GALVANO-THERAPEUTICS.

THE

PHYSIOLOGICAL AND THERAPEUTICAL

ACTION OF THE GALVANIC CURRENT UPON THE ACOUSTIC, OPTIC, SYMPATHETIC, AND PNEUMOGASTRIC NERVES.

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PREFACE.

Since writing my first essay, in 1852, "Diagnosis of Diseases of the Nervous Centres," to which was awarded the prize of the Imperial Medico-Chirurgical Academy of St. Petersburg, I have continued to take the deepest interest in diseases of the nervous system. The largest hospital of St. Petersburg, to which I was a visiting physician, and its dissecting-room, offered me a vast field of observation. My facilities for investigating these diseases became still more extensive when I was sent by the Russian Government to Germany, France, and England, to qualify myself for a chair of medi-

cine for medical graduates. Although devoting myself there to clinical medicine and its collateral sciences (histology, physiology, and chemistry), the study of nervous diseases yet remained my favorite occupation. Thus, for a number of years, I was enabled to work in the different universities of Europe under the guidance of the very men to whose great discoveries we are indebted for the present advanced state of our knowledge.

I am preparing for publication the result of my studies, in two volumes. The first will be a treatise on diseases of the nervous system ; the second will treat of the galvanic current in its relation to physiology, medicine, and surgery. The present article is a part of the last work, and appears now in print at the request of several aural surgeons and other professional gentlemen.

I sincerely hope to convince the reader in the following pages that even the treatment of nervous diseases has recently made great progress, and that, to insure success, it must be based on the knowledge of physics and physiology.

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GALVANO-THERAPEUTICS.

I.

THE GALVANIC REACTION OF THE ACOUSTIC NERVE IN ITS HEALTHY AND DISEASED CONDITIONS: BEING THE BASIS FOR THE RATIONAL TREATMENT OF SOME OBSTINATE AFFECTIONS OF THE AUDITORY ORGAN. ELECTRO-OTIATRICS.[1]

THE galvanic current has been applied to therapeutics since the discovery of the pile, and first by Volta himself, though mostly with negative results. Indeed, nothing else could have been expected, as electro-physiology did not yet exist, and the apparatuses at command were imperfect and unfit for medical purposes.[2]

[1] Paper read before the New York Medical Journal Association, June 10, 1870.

[2] It is surprising that, in some quite recent publications, apparatuses should have been introduced of a perfectly primitive con-

It was, therefore, natural that the profession should direct their whole attention to the induced currents discovered by Oersted and Faraday; and the more so, since the action of electric currents derived from different sources was considered identical, and with the improved apparatuses the induced currents could be more easily applied. With Du Bois-Reymond's discoveries in electro-physiology begins a new era for the application of the galvanic current to the treatment of diseases. Crussel discovered the electrolytic, and Middeldorpf the galvano-caustic methods, and in 1855 Remak began his first researches in electro-therapeutics. His reputation was already firmly established by his classical researches and his great discoveries in normal and pathological histology, especially that of the nervous system, and, above all, in embryology. Duchenne's[1] beautiful investigations first attracted Remak's attention to elec-

struction. Besides leading the profession to incur useless expenses, they present none of the advantages indispensable for medical and scientific purposes, and can only discredit the method itself.

[1] Duchenne (de Boulogne), "De l'Electrisation localisée et de son application à la Physiologie, à la Pathologie et à la Thérapeu-

tro-therapeutics. In repeating Duchenne's experiments, Remak improved his method of localized electrization by showing that a complete contraction of the whole muscle is much better effected by exciting its motor nerve than by exciting the muscle itself; and that the so-called "points d'election," empirically found by Duchenne, are nothing else than the places of entrance of the nerves into the muscles. Remak then began to study the difference of the effects of the different electrical currents, both in the healthy and in the diseased subject, and soon found that the galvanic current possesses far superior therapeutic properties to the induced currents, and that very often, where the former may be beneficial and effect a cure, the latter will be useless or even injurious. The galvanic current alone exercises a direct action upon the organs of special senses, as well as upon the nervous centres. The galvanic current, but not the induced currents, produces the electrotonic state in the nerves and nervous centres.

tique." Paris, 1855. His first article, however, had been presented to the Academy of Sciences in 1847.

One of the chief advantages of the galvanic current is, that, in a painless way and without a shock, we can introduce into the system a large amount of electricity, which is often indispensable, considering the enormous resistance of the body to the electric current. In his electro-therapeutic experiments, Remak was always guided by the physiological action of the galvanic current, and it was his constant aim to establish a rational electro-therapeutics on the physiological laws of electrotonus. Remak published numerous articles on the galvanic current, of which we mention here his principal work, "*Galvanotherapie der Nerven und Muskelkrankheiten.*" Berlin, 1858.

Notwithstanding his great merits as an investigator in the domain of pure science, his researches in electro-therapeutics were met with general skepticism, and even ridicule, so wonderful seemed the phenomena he described, and so miraculous the cures he had effected. In vain had he presented to the Berlin Medical Society cases of locomotor ataxy, first in their hopeless condition, and then after a cure had been effected:

it only aroused doubts as to the diagnosis, for the correctness of which a *post-mortem* examination was yet wanting. Remak sarcastically answered that it was his object to save his patients from the *post-mortem* table. At last he went to Paris in 1864, and delivered lectures with demonstrations on patients before a committee appointed by the Academies of Sciences and of Medicine. His "*Application du Courant constant au traitement des Nevroses, leçons faites à l'Hôpital de la Charité*," contains an excellent and concise exposition of his doctrines. After his death it was unanimously acknowledged that he was a great genius, and that he has endowed therapeutics with one of its best and most powerful agents.

At the present time it is universally admitted by the highest medical authorities that the scientific use of the galvanic current is the most efficient and rational treatment of diseases of the nervous system, and that some morbid conditions can be treated successfully only by this means.

The apparatus for the galvanic current, which

I am in the habit of using, and which is generally used by the best electro-therapeutists of Europe, is the one introduced by Remak, with elements of Siemens. It was first constructed by Siemens and Halske, and improved by Krüger and Hirshman, of Berlin, and enables us to introduce into the circuit any number of elements. But, whatever battery may be used for the generation of the galvanic current, several conducting apparatuses are indispensable for scientific and medical purposes. All the changes in the density of the current (with a few exceptions), the closing, breaking, and reversing, of the current, have to be accomplished within the metallic part of the circuit; for only in this way are we enabled to observe the most interesting and important phenomena which accompany the galvano-therapeutic experiment, and in this way alone can we arrive at a correct diagnosis and prognosis, and accomplish a successful treatment. It is scarcely necessary to mention that the conducting wires, besides being well isolated, must be wound round and soldered to the metallic pieces, connecting

them with the electrodes, and with the apparatus, lest they get loosened or broken off. Trifling as this may seem, it is not so for the patient whose head, or acoustic or optic organ, is intercalated within the circuit, and who receives a terrific and dangerous shock, or an uncalled-for intense reaction of the acoustic or optic nerve, merely through the neglect of this slight precaution. The hollow metallic cylinders with sponges, formerly used as electrodes, must be entirely banished from the electro-therapeutic practice.

It is further indispensable to possess a *current-selector*, a contrivance that will enable us, while the current is flowing uninterruptedly, to increase or diminish its intensity, by introducing or removing any number of elements.

For controlling with a mathematical precision the current-density within very small graduations, a special apparatus is indispensable, without which it is often perfectly impossible to make a correct diagnosis. Many obstinate neuralgias or diseased conditions of the higher senses can only be successfully treated when we possess the means of graduating

the current-density in so imperceptible a way as to avoid altogether the morbidly-increased reactivity of the affected nerves. Such a graduation can be accomplished by adding an accessory circuit to the one in which the body is intercalated. If we introduce a varying amount of resistance into the accessory circuit, the density of the current flowing through the main circuit changes accordingly; the more resistance the current meets in the accessory circuit the greater will be the density of the current traversing the body, and *vice versa*. Siemens's rheostat, by means of which twenty-one hundred units of resistance[1] can be introduced into the accessory circuit, answers the purpose very well. This renders it easy to increase or diminish the current-density with great precision and rapidity, as well as to graduate imperceptibly the intensity of any number of elements into twenty-one hundred degrees. Indeed, the advantages of this method of applying the galvanic current are in-

[1] Siemens's unit of resistance is a prism of chemically pure mercury, one metre long and one mm. square transverse section at the temperature of 0°C.

valuable, as it admits of the painless administration of great current-intensities, which are often absolutely requisite to call forth the reaction of a nerve. The proper management of the rheostat requires a great deal of experience and technical dexterity, and belongs to the most difficult and delicate electro-therapeutic operations. The merit of having introduced this instrument into practical electro-therapeutics belongs to Brenner, of Russia, who has made most excellent and valuable investigations, and who considers this conducting apparatus indispensable for exactness of diagnosis and treatment.[1] From my own experience, I can only confirm all his statements, and I am fully convinced that the skilful management of the rheostat, as an accessory circuit, is of the utmost value for scientific electro-therapeutics. Without it many remarkable phenomena utterly escape observation, and various diseased conditions cannot at all be diagnosticated or treated successfully.

In connection with the battery, there must be a

[1] Brenner, Untersuchungen und Beobachtungen, auf dem Gebiete der Electrotherapie. Leipzig, 1868. Bd. I., p. 15.

commutator, by means of which the direction of the current can be instantly reversed. The sudden reversion of the current-direction being the greatest stimulus to the nerve, it is evident that the commutator is the most important conducting apparatus in electro-therapeutics. Those who reverse the current-direction by merely changing the respective electrodes on the surface of the interealated body, cannot possibly observe some of the most interesting phenomena so valuable for electro-diagnostic and therapeutic purposes.

Besides these, an apparatus is requisite for the uniform and rapid interruption of the constant current.

For diagnostic purposes, a rheotome like the one described by Fick[1] is very useful. By means of it the duration of the current and of its interruptions can be regulated and measured with great accuracy.

Finally, in connection with the galvanic apparatus, there must be a galvanoscope, indicating

[1] A. Fick, Untersuchungen über electrische Nervenreizung. Braunschweig, 1864, p. 5.

the direction of the current, its approximate intensity, and its constancy or fluctuations.

The electrodes, according to Remak, may be applied immovably (stabile Ströme), which is indicated by the immobility of the galvanoscopic needle. This mode is used invariably when a really constant current is required; and this is always understood when speaking of the galvanic current. Or, one electrode may be fixed, and the other moved, without, however, breaking the circuit. This method produces fluctuations of the current-density by the continuous change of the resistance, as indicated by the oscillations of the galvanoscopic needle; it is more exciting, and constitutes in some degree a transition to the interrupted current. As this method cannot render manifest the most important phenomena accompanying an electro-therapeutic experiment, and thence cannot be used for electro-diagnostic purposes, it is of little value for scientific electro-therapeutics.

The third mode of applying the electrodes, according to Remak, is the so-called unipolar meth-

od,[1] where we place on the affected part but one electrode, the action of which we intend to bring into play, applying the other to some indifferent place. As we are often unable to ascertain what direction the current will take in the uninjured living body, Brenner insists upon the general adoption of this method,[2] which he calls the polar method.

The general effect of a prolonged application of the galvanic current is soothing, with an increase of temperature and subsequent perspiration, and is almost always followed by a prolonged, refreshing sleep. My patients invariably report that they sleep well, even when the current was applied for other purposes.

The local effects of the galvanic current differ extremely, according to the organs brought under its influence.

The object of this paper is to show the important influence of the galvanic current upon the acoustic nerve, upon which, as well as upon the

[1] Remak, Application du Courant Constant, p. 7.

[2] Brenner, Electrotherapie. Leipzig, 1868, p. 2.

nerves of the higher senses, and upon the nervous centres, the induced currents produce no effect whatever in the uninjured living subject.

PHYSIOLOGICAL PART.

Soon after Galvani's great discovery, published in his famous work, "De Viribus Electricitatis in Motu Musculari Commentarius, 1791,"[1] Volta began experimenting with the organs of the senses, in order to demonstrate the continuous flow from the newly-discovered electric source.[2]

Already, with a single pair of metallic plates, he had been able to excite the sensitive, the gustatory, and the optic nerves, an experiment soon confirmed by other observers, especially by Humboldt.[3] After the discovery of the pile, Volta could call forth these phenomena with greater cer-

[1] Opere edite ed inedite del Professore Luigi Galvani raccolte e publicate per cura dell' Academia delle Scienze dell' instituto di Bologna. 1841.

[2] Collezione del opere del cavaliere Conte Alessandro Volta, Patricio Comasco, Firence 1846. T. II., P. I., p. 116.

[3] Al. v. Humboldt, Versuche über die gereizte Muskel-und Nervenfaser, etc. Berlin und Posen, 1797, Bd. I., p. 196.

tainty, and even excite the olfactory and auditory organs. With the auditory organ he proceeded as follows: he introduced into both ears metallic probes, connected with the poles of a pile consisting of thirty or forty pairs, and at the closing of the circuit and during the flow of the current, he experienced a peculiar acoustic sensation — like the boiling of a viscid fluid.[1] He did not, however, repeat this experiment, as the reaction of the acoustic was accompanied by very unpleasant and dangerous cerebral symptoms.

After him, the young and indefatigable Ritter, among his innumerable experiments in animal electricity, made some heroic and almost suicidal ones on his organ of hearing.[2] Introducing both ears into the circuit of a battery of one hundred or two hundred elements, he experienced a distinct musical tone at the closing and breaking, as well as during the continuance of the current. But, as, even with a pile of only thirty elements,

[1] Volta, *op. cit.*, p. 126.

[2] Ritter, Beiträge zur nähern Kenntwiss des Galvanismus, etc. Jena, 1802. *Vide* Du Bois-Reymond, Untersuchungen über thierische Electricität. Berlin, 1848–'60. Bd. I., p. 344.

the acoustic experiment of Volta was unpleasant and dangerous, it is natural that Ritter's fearful experiments with one hundred or two hundred pairs to call forth the acoustic reaction should not have found imitators.

At the beginning of this century, several physicians used the galvanic excitation with simple chains in the treatment of deafness and other affections of the ear. I mention especially Grapengiesser,[1] who describes the acoustic reaction as a peculiar murmur or noise. But, with Volta's victory over Galvani, the experiments on animal electricity were soon abandoned, and with them went into oblivion the galvanic reaction of the acoustic nerve. Recent physiologists doubted altogether the possibility of exciting the acoustic organ by electricity; and, until lately, no aural surgeon thought of the value of the galvanic current for the diagnosis or treatment of aural diseases.

I will here mention an important assertion of

[1] Grapengiesser, Versuche den Galvanismus zur Heilung einiger Krankheiten zu benutzen. Berlin, 1801.

Remak, which I think has escaped the attention of physiologists and electro-therapeutists. As in other branches of electro-therapeutics, here too he has given valuable hints which have been fully corroborated and developed by the excellent investigations of Brenner.[1] Remak says:[2] "Le nerf acoustique est plus sensible à la sortie du pole positif qu'à l'entrée, et plus sensible à l'entrée du pole négatif qu'à la sortie; enfin il se comporte comme un nerf sensible. Dans la surdité provenant des centres nerveux on observe que l'une des deux electrodes produit des effets croisés à la manière des contractions reflexes croisées que j'ai observées dans l'atrophie musculaire progressive," etc.

This sentence of Remak's, together with his unipolar method, forms, in my opinion, the nucleus of Brenner's researches, although the latter does not mention it. Nevertheless full credit must be given to Brenner, to whose patient, difficult, and conscientious investigations we are indebted for one of the

[1] R. Brenner, Untersuchungen und Beobachtungen, auf dem Gebiete der Electrotherapie, Bd I., Abt. I., Leipzig, 1868 and 1869.

[2] Remak, Application du Courant Constant, etc., p. 6.

exactest parts of scientific electro-therapeutics, a detailed account of which I am going to give here. I have myself made numerous experiments on the healthy and diseased auditory apparatus, and can fully confirm all the statements of Brenner, as has been done by Erb,[1] Hagen,[2] and others. It seems strange, therefore, that Brenner's researches, made with such perseverance and such thorough knowledge of his subject, should yet be contradicted by Schwartze,[3] Schultz,[4] and others. This can only be explained by supposing that those who have repeated his experiments were not sufficiently acquainted with physics and electro-physiology, or did not possess the skill and delicacy of manipulation indispensable for experimenting on the auditory organ.

Brenner has demonstrated that the acoustic nerve answers the galvanic excitation, with a cer-

[1] Erb, Die galvanische Reaction des nervösen Gehörapparats im gesunden und krankhaften Zustande. Also in English, in Profs. Knapp and Moos's Archives of Ophthalmology and Otology, vol. i., p. 232.

[2] Hagen, Electro-otiatrische Studien. Leipzig, 1866.

[3] Archiv für Ohrenheilkunde, Bd. I., Heft I.

[4] Ibid., Bd. II., Heft II., p. 155.

tain characteristic reaction, more readily than any other motor or sensitive nerve, and that this reaction is of the utmost value for diagnostic and therapeutic purposes. But, for the rational application of this acoustic reaction to diagnosis and therapeutics, great experience is required on the part of the physician in the use of the apparatuses already enumerated; for the galvanization of the acoustic is very difficult on account of the accompanying unpleasant phenomena, which can only be avoided by certain skilful manœuvres. Indeed, if we galvanize the ear in the usual way—for instance, by introducing one electrode (the end of an isolated wire) into the meatus filled with water, placing the other electrode upon the mastoid process, or upon the temple, and then passing the full strength of a galvanic current, though from a small number of elements—our attempt to call forth the reaction of the acoustic nerve will be frustrated; long before we arrive at the necessary current-intensity, the disturbing symptoms attending such a rough method of application will compel us to desist. In the first place, the pain produced in the sensitive

nerves of the tympanic membrane, and the walls of the meatus, will be intense and steadily increasing with the duration of the current. As the current penetrates in great density through the thin wire-electrode, the pain gets more intense and becomes perfectly unbearable when, for the increase of the current-intensity, the circuit is opened and closed. According to Brenner, the pain is quite characteristic for each electrode. When the positive electrode is in the ear, the pain is accompanied by a sensation of pressure, entering from without toward the tympanum. When, on the contrary, the negative electrode is applied, a sensation of something apparently pressing outward is felt; so that the person on whom the experiment is made can distinguish with great precision the direction of the current.

Besides the intolerable pain which does not allow the increase of the current-intensity to a degree necessary for the provocation of the specific acoustic reaction, such a galvanization will be attended by muscular contractions in the sphere of the facial nerve, and of the motor branch of the

fifth pair. These nerves are necessarily affected by the current, and hence the contractions of the orbicularis palpebrarum, zygomaticus, corrugator supercilii, frontalis, occipitalis, masseter, etc. The muscular contractions follow a certain law minutely studied on the living subject, and formulated by Brenner.[1]

One of the most disturbing phenomena accompanying the galvanization of the auditory organ is *vertigo*, with loss of equilibrium, nausea, and other dangerous cerebral symptoms. Vertigo very often attends also the application of the electrodes to the fossa auriculo-maxillaris,[2] and to the head. According to Brenner,[3] whose statements I can fully confirm, vertigo never appears, no matter how strong the current may be, when the electrodes are so applied that a supposed line connecting them is parallel to the plane passing through the antero-posterior diameter of the head. But, as soon as the line connecting the electrodes forms an angle with this plane, vertigo will invariably

[1] Brenner, *op. cit.*, Bd. II., p. 42. [2] Remak, *op. cit.*, p. 7
[3] *Op. cit.*, Bd. I., p. 75.

take place, and will be intensest when the angle is a right one. Even very feeble currents readily produce vertigo, when applied in this way, especially at every change of the current-direction and intense currents may cause vomiting and syncope. In this loss of equilibrium, the falling always takes place on the side of the anode during the closure of the current (Brenner), and on the side of the cathode at the breaking of the circuit (Benedikt).[1]

The galvanization of the ear is attended also by characteristic optic phenomena, in consequence of the current's penetrating to the optic nerve, the description of which will be given hereafter.

Lastly, gustatory sensations, salivation, cough, and other symptoms, are often observed.

The above-described disturbing phenomena can be in a great measure avoided by increasing or diminishing the number of elements slowly and gradually, without interrupting the circuit, and especially by establishing an accessory circuit, in which the rheostat is intercalated. Thus we are

[1] Benedikt, Electrotherapie, Abt. I., p. 207.

enabled to graduate the current-density which traverses the body, by introducing various resistances into the accessory circuit, and by very small gradations we imperceptibly bring the current to a sufficient density to excite the acoustic apparatus without calling forth the other disturbing phenomena. The vertigo and the other cerebral symptoms produced by an improper mode of applying the electrodes can always be avoided.

Again, the membrana tympani being so extremely sensitive, it is better not to introduce the ear-electrode into the meatus, but to apply a button-shaped electrode to the tragus, pressing it inward so as to occlude the meatus.

As the ear-electrode is the one whose action we desire to bring to bear upon the acoustic apparatus, the other electrode, the indifferent one, must not be applied to the temple or the mastoid process, as was formerly done, but rather to a distant part (for example, the neck or the hand), unless for some special purpose other localities be chosen. By not placing the second electrode to the head, a great part of the disturbance is obvi-

ated, and the characteristic polar action of the current comes distinctly into play. The great distance between the electrodes increases the resistance to the current and reduces its density, so as not to allow it to excite sufficiently any other structure except the auditory organ. On this latter its action is concentrated, and the density of the current flowing through the ear-electrode is still more increased by taking the second electrode of a large size.

Before considering the special action of the galvanic current upon the acoustic nerve, it will be useful to recall some physiological points pertaining to its action upon the nerves in general. We shall then see that the laws of electro-physiology, derived from experiments upon the motor nerves, can be applied to the acoustic nerve as well; and, moreover, in the living subject they can be demonstrated on this nerve even more easily than on any other.

Du Bois-Reymond has shown that the galvanic current, traversing any part of a nerve, produces in the whole of it a distinct molecular change,

the dipolar or pile-like polarization of the electromotor molecules of the whole nerve, the so-called electrotonus.[1]

Pflüger[2] has discovered that in the electrotonic state the irritability of the nerve undergoes a striking change: it is wonderfully exalted in the region of the cathode (catelectrotonus), and lowered in the region of the anode (anelectrotonus). He has further shown that the nerve is excited only by the appearance of catelectrotonus and by the disappearance of anelectrotonus, and that the appearance of catelectrotonus excites the nerve in a higher degree than the disappearance of anelectrotonus. The moment the circuit is closed, the catelectrotonus is strongly developed —increasing, however, with the duration, as of course with the intensity, of the current. The anelectrotonus, on the other hand, develops itself gradually and slowly. Each of these conditions leaves, after the breaking of the current, the

[1] Du Bois-Reymond, Thierische Electricität, Bd II., p. 289.

[2] Pflüger, Untersuchungen über die Physiologie des Electrotonus. Berlin, 1859.

positive modification, that is, increased irritability of the nerve for the same current-direction, and still more for the opposite one.

All the experiments upon the acoustic apparatus are to be instituted by Remak's unipolar (Brenner's "polar") method, which is based on the property of the nerves to react only to the nearest electrode, the one separated from it by less resistance; the other electrode remaining ineffieient.

If we apply the cathode of a weak current to the ear, and the anode to the neck or the hand, closing the circuit in the metallic part in which a commutator is interealated, a prickling, burning sensation is felt at first, followed by the other symptoms accompanying the galvanization of the ear. On increasing the intensity of the current, a sound is perceived, usually a distinct, metallic ringing. This acoustic pereeption is most distinct at the closing of the eireuit, lasting but a few seconds of the current-duration, and not reappearing at the breaking of the circuit. On reversing the current-direction by means of the eommutator, so that the ear-electrode becomes the anode, and the

indifferent one the cathode, no acoustic sensation is perceived, either at the closing of the current or during its continuance. This sensation appears again, however, at the breaking of the circuit, when it is like that perceived at the cathodic closing, though feebler and of less duration. This reaction of the acoustic may be expressed by the following formula (Brenner):

KaCS: The closing (C) of a galvanic current produces an acoustic sensation (sound, S) when the auditory organ is under the influence of the cathode (Ka).

KaDS>: This acoustic sensation continues with diminishing (>) intensity, and soon completely disappears during the continuance (duration, D) of the current.

KaO—: At the opening (O) of the circuit, no acoustic sensation is perceived.

AnC—: At the closing of the circuit, when the auditory organ is under the influence of the anode (An), no acoustic sensation is felt.

AnD—: In the anodic duration: no acoustic sensation.

AnOS: At the anodic opening, however, the same sound is heard as at the cathodic closing, but of less intensity (s), and less prolonged.

The reaction of the acoustic nerve may sometimes be produced with a few elements; but it never appears at the cathodic opening or the anodic closing, however the current-intensity be increased. This is evidently in accordance with the physiological law of Pflüger, already mentioned, that the nerve is excited only by the appearance of catelectrotonus and the disappearance of anelectrotonus, and more so by the first than by the last. On placing the cathode into one ear, and the anode into the other, the acoustic reaction in the different ears will be at opposite moments: while in the one ear the reaction occurs at the cathodic closing and the anodic opening, in the other ear there will be at these moments no acoustic sensation, and *vice versa*.

Right ear (under cathode).	*Left ear* (under anode).
KaCS	—
KaDS>	—
KaO—	S
AnC—	S
AnD—	S>
AnOS	—

But this mode of applying the electrodes must be avoided, as it produces vertigo. With the increase of the current-intensity, the sound, while commonly retaining its quality, becomes higher in pitch when under the influence of the cathode, and lower under that of the anode.

Brenner has proved that the reaction of the acoustic nerve is produced by the galvanic current directly affecting this nerve itself, and not through a reflex action from the trifacial, as supposed by Benedikt and others. Brenner demonstrated this by a direct experiment. He introduced two needles into the semicircular canal of the labyrinth in the dead subject, connecting them with the wires of a galvanometer. On applying both electrodes of the galvanic current in the same manner as for the galvanization of the auditory organ in the living subject, viz., one electrode to the meatus and

the other to the neck, the galvanometer-needle was instantly deflected. Moving the neck-electrode nearer to the ear-electrode, a greater current-intensity was requisite to produce the same deflection, and when nearly approached to each other no deflection of the needle could possibly be obtained. This experiment shows that the terminations of the acoustic nerve are traversed by the current when the auditory organ is galvanized, especially by the polar method. The older method of application, with the electrodes near each other, is less efficient, because the current passing from one electrode to the other through the nearest conducting substances forms, as it were, an accessory circuit, and evades the acoustic nerve altogether.

It is also evident, from the following considerations, that the specific reaction of the acoustic nerve is not dependent upon the reflex action from the sensitive nerves of the fifth pair. In the first place, the existence of a reflex action from the sensitive nerves upon the organs of the special senses has never been demonstrated, and is alto-

gether doubtful. Again, the intensest excitation of the sensitive nerves with induced currents never calls forth the acoustic reaction. And, lastly, the intensity of the galvanic excitation is in direct ratio to the acoustic reaction, which, as a rule, would not be the case with reflex phenomena.

The galvanic reaction effected in the way described, viz., by using besides the battery only a commutator and a current-selector for changing the number of elements while the current flows uninterruptedly, is yet a comparatively rough proceeding, at least a very imperfect mode of treating the acoustic apparatus. It is more or less painful, and is not sufficient for all diagnostic and therapeutic purposes. To make the galvanization of the auditory apparatus more exact and very much milder, it is necessary to intercalate the rheostat, as an accessory circuit.

In Brenner's formula the number of elements is marked by Roman figures, and the number of resistances in the rheostat by Arabic. As a rule, twenty Siemens's elements are quite sufficient for investigations upon the acoustic apparatus. To

begin with, but very few resistances are introduced into the accessory circuit; then their number is gradually increased until an acoustic sensation is perceived. The following may serve as an example.

W—, with a perfectly healthy auditory apparatus. One electrode in the ear, the other in the hand.

XX10KaC—: With 20 elements and 10 resistances of the rheostat, no acoustic sensation is felt at cathodic closing.

XX20KaC—: The same with 20 resistances.

XX30KaCS′: With 30 resistances a distinct musical sound is perceived.

KaDS>: This sound disappears by degrees during the continuance of the current.

KaO—: No acoustic sensation at cathodic opening.

AnC—: The same at anodic closing.

AnD—: The same at the anodic duration.

AnOS—: Sound at the anodic opening, similar in character to KaC, but weaker and shorter.

The acoustic sensation produced by the galvanic current is commonly that of a clear, high, sharp, metallic sound, sometimes of a pleasant and distinctly musical character, like the ringing of a bell, the sound of a stretched cord, as of a guitar or other stringed instrument, the sound of a glass or of vibrating metallic plates. Sometimes the sensation produced is that of a murmur; it may be like the distant explosion of a cannon, the rolling of a heavy vehicle, or whistling, hissing, buzzing, and many other noises. In every individual the acoustic sensation is always found the same when produced under similar conditions, and with the same current-intensity. In the normal condition the sound becomes higher with increasing current-intensities under the influence of the cathode; and deeper under the influence of the anode. In pathological conditions different current-intensities may produce different acoustic sensations, though always of the same character in the same person. The lower current-intensities usually call forth murmurs, the higher intensities musical sounds. This harmonizes with the results

of Helmholtz's researches, according to which the organs for the perception of murmurs are situated within the vestibule, and those for the perception of musical sounds in the cochlea. The former, being the nearest, are the first excited with weaker current-intensities.

The acoustic nerve reacts only to the nearest electrode; the distant one remaining unanswered. When both electrodes are close to the ear, the acoustic excitation becomes difficult and often impossible even with high current-intensities; yet the reaction, when it occurs, is always in favor of the nearest electrode. In such a case it can be easily determined under the influence of which electrode is the acoustic nerve, because, if it reacts at the closing, it is under the influence of the cathode, and if, on the contrary, it answers to the opening, it is under that of the anode. By this means Brenner[1] has found (and it is easy to ascertain the correctness of his assertion) the different places in the vicinity of the ear which present the least resistance to the penetration of the current

[1] Brenner, *op cit.*, p. 118.

to the acoustic nerve. On the whole, this nerve is more easily excited from the points surrounding the lower part of the ear than from those about the upper part, and more easily from the anterior side than from the posterior.

Fluctuations of the current-density are of very high importance with regard to the reaction of the acoustic as well as of any other nerve. While small fluctuations, especially those almost imperceptible ones which may be produced with the rheostat, exercise no marked influence upon the nerve, the sudden density-fluctuations, and particularly those of great magnitude, act as closings and openings of the current. Indeed, the closing and opening of a current are nothing else than the greatest fluctuations of its density from zero to maximum, and from maximum to zero, giving therefore the strongest reaction. Brenner has demonstrated that increasing fluctuations (fluctuations in the positive direction) act as closings, and decreasing fluctuations (in the negative direction) as openings. Consequently, under the influence of the anode, the acoustic nerve will answer with

an acoustic sensation only to the decreasing fluctuations, because they correspond to the anodic opening, while advancing fluctuations of the current-density, corresponding to the anodic closing, will remain unanswered, no matter how great and sudden they may be. On the contrary, under the influence of the cathode, the acoustic nerve will react only to every positive fluctuation of the current-density, leaving unanswered the fluctuations in the negative direction, be they never so great.

To produce the effect of closing and opening, the fluctuations must be of a very sudden character and made in the metallic part of the circuit. Very considerable fluctuations produced by a slow and gradual lifting of the electrode from the surface of the body may not call forth the reaction of a nerve (or muscle).

Again, Brenner has shown that the greater a given current-intensity, the larger must be the fluctuation necessary to effect the acoustic reaction.

Lastly, the duration of the current traversing the acoustic nerve very greatly increases its ex

citability, as the following example will illustrate:

XX10KaC—
20KaC—
30KaC—
40KaC—
50KaCS

In this case, XX50KaCSEI expresses, according to Brenner, the formula of the *primary excitability* of the acoustic nerve. If the nerve be exposed to the action of this current-intensity during several seconds, we shall find that, in consequence of the catelectrotonic condition produced by the galvanic current, its irritability has so increased that now it will react with smaller current-intensities: for instance, we may obtain an acoustic sensation with forty resistances, and even with thirty resistances, though not with less.

XX40KaCS
30KaCS
20KaC—

Therefore, the formula XX30KaCSEII[20] expresses the *secondary excitability* of the acoustic

nerve, showing that it has increased by twenty resistances of the rheostat. If, after this, the nerve be subjected to the most powerful of all electric stimuli, the current-reversal, its irritability will be still more increased, and it will react to such small current-intensities as it could not answer before. So, for instance, after the influence of XX30AnC and AnD, an acoustic reaction is obtained with twenty and ten resistances:

XX20KaCS

10KaCS

The formula XX10KaCSEIII^{20}, ^{20} expresses the *tertiary excitability* of the acoustic nerve, and is also measured (in this example) by twenty resistances of the rheostat. Having any one of these formulæ, we can easily reconstruct the others. In this way we are enabled to make an exact diagnosis of the condition of the nervous apparatus of the auditory organ, and to ascertain, at any given moment, how far this condition has improved under our treatment.

The foregoing is again a beautiful illustration of the fact that the acoustic nerve in the living

human body obeys the same laws of electrotonus discovered by Pflüger in the motor nerve of the frog. The acoustic nerve, like the motor, undergoes an increase of irritability after a galvanic current has traversed it, and more especially in an opposite direction.

The result of the action of the galvanic current upon the acoustic nerve in the healthy condition may be summed up as follows:

1. The continuous galvanic current can call forth the specific energy of the acoustic nerve in a certain characteristic manner.

2. This normal reaction of the acoustic nerve consists in an acoustic sensation, which is felt under the influence of the cathode at the closing, and for a short time during the closure of the circuit; and, under the influence of the anode, only at the opening of the circuit. The cathodic opening and the anodic closing are not answered by an acoustic sensation.

3. The cathodic reaction, which appears almost in its full strength at the closing of the circuit, soon decreases and disappears altogether. The

anodic opening reaction appears gradually, and requires that the preceding anodic closure should be of considerable duration; otherwise the anodic opening will not call forth an acoustic sensation.

4. After the cathodic opening, the acoustic nerve, being in the electrotonic state with increased irritability, reacts at subsequent cathodic closings to smaller current-intensities than it could do before. The same takes place in a still higher degree after reversing the current-direction.

5. The acoustic reaction is called forth not only by the closing and breaking of the current, but also by sudden and large fluctuations during the uninterrupted flow of the current. Fluctuations, with increasing intensity, have the same effect as the closing; and fluctuations, with diminishing intensity, the same as the opening of the current.

6. The acoustic sensations, produced by the galvanic current, are various in different persons, though always identical in the same. They resemble buzzing, hissing, rolling, whistling, ring-

ing, etc., and in their highest development pure, pleasant, musical notes of a different tone in different persons. Very often the murmurs correspond to lower current-intensities, and the metallic ringing and musical sounds to the higher intensities.

7. On increasing the current-intensity, the sound becomes higher when the acoustic nerve is under the influence of the cathode, and lower when it is under the influence of the anode.

PATHOLOGICAL PART.

The morbid alterations of the galvanic reaction of the acoustic nerve may have their cause either in the nervous apparatus itself or in the conducting structures of the auditory organ. These latter offer sometimes an exceedingly great resistance to the penetration of the current to the acoustic nerve, as, for example, accumulation of hardened ear-wax, deposits of morbid products, adhesions, etc., and in these cases enormously great current-intensities are required for the production of the acoustic reaction. On the other

hand, the resistance may be abnormally lessened by suppuration, ulceration, defects, etc. And here, as, for instance, in a perforation of the tympanic membrane, scarcely noticeable by inspection, the galvanic reaction is produced with unusually weak current-intensities, sometimes with a single element; while, in atresia of the external meatus, or its occlusion by hardened wax, twenty elements and more are insufficient for that purpose.

On passing a galvanic current through the ear, we invariably observe that the walls of the meatus, and especially the tympanic membrane, become injected and covered with a uniform red color, and the patient experiences a sensation of warmth in the ear. If the galvanization is repeated methodically, the vascular excitation increases the metamorphosis of tissue, and patients with chronic ear-diseases notice an increased secretion of ear-wax, or this secretion reappears after having ceased altogether for many years. Brenner[1] has repeatedly seen absorption of pathological deposits in the membrana tympani, of many

[1] Brenner, *op. cit.*, p. 233.

years' standing; and Hagen,[1] a well-known aural surgeon, has cured in the same way inveterate opacities and thickening of the tympanic membrane, which had resisted every other treatment. A similar case has occurred in my own practice.

The normal galvanic reaction of the acoustic nerve is an indispensable manifestation of its healthy condition, and every deviation from it is a sign of disease. We have seen already that the normal formula of the galvanic reaction is, according to Brenner:

KaCS
KaDS >
KaO—
AnC—
AnD—
AnOS.

It can undergo alteration in three different ways. The excitability of the acoustic nerve may be either morbidly increased (a condition called by

[1] Hagen. Praktische Beiträge zur Ohrenheilkunde, part vi., p. 40. Leipzig, 1869.

Brenner[1] *hyperæsthesia* of the acoustic nerve), or it may be greatly diminished (torpor of the nerve). Again, besides these quantitative alterations, there may be a qualitative change of the acoustic reaction.

SIMPLE HYPERÆSTHESIA OF THE ACOUSTIC.

Hyperæsthesia is a very common aural disease, and cases exhibiting it are extremely convenient for the study of the galvanic reaction of the acoustic. Hyperæsthesia manifests itself by the great facility with which the acoustic nerve answers the galvanic current, a very low intensity being sufficient to call forth the acoustic reaction. The "primary excitability" is, therefore, very low. The cathodic duration-reaction, instead of lasting, as normally, only a few seconds, continues throughout all the time of the cathodic closure; and the anodic opening-reaction is more prolonged, and more intense than in the normal formula. In this condition the smallest fluctuation of the current-density, even the slightest shifting of the electrode,

[1] *Op. cit.*, p. 181.

readily produces an acoustic sensation. In the highest forms of hyperæsthesia it is not indispensable to apply the electrode to the ear; on placing it at any point of the head or neck, the galvanic reaction will be called forth from the acoustic nerve of the nearest side.

Very characteristic of hyperæsthesia is the magnitude and also the duration of the secondary and tertiary excitabilities; all three degrees of excitability are very distant from each other, presenting large figures, and lasting very long. The following case of hyperæsthesia will illustrate these points:[1]

X400KaCS″
KaDS′∞
KaO—
AnC—
AnD—
AnOS>

It is seen in this formula that, with a comparatively feeble current, a very intense acoustic sensation is produced at the cathodic closing, and con-

[1] s, S, S,′ S ″ signify sound of different degrees of intensity.

tinues indefinitely during all the time of the cathodic closure; it disappears at the cathodic opening; remains absent at the anodic closing, and in the anodic duration; and reappears at the anodic opening, but with more strength, and lasting longer than in the normal galvanic reaction.

In this case X400KaCSEI being the primary excitability of the acoustic, X200KaCSEII^{200} represented the secondary excitability, and X80KaCSEIII^{200,120} the tertiary excitability, all of these being of longer duration and greater intensity than in the normal formula. As can be seen in these formulæ, the different degrees of excitability are separated by very large figures.

Hyperæsthesia of the acoustic nerve is almost always accompanied by most distressing subjective acoustic sensations—by different noises.

The causes of hyperæsthesia are various. When they are outside of the acoustic nerve, in the affected conducting structures of the auditory organ, which prevent the sound from reaching the nerve, this latter, being deprived of its normal stimulus, becomes hyperæsthetic in the same way

as the optic nerve, when, after prolonged privation of light, we begin to see in the darkness. But this condition does not last indefinitely; on the contrary, the acoustic nerve, like the optic, deprived of its normal stimulus, becomes, after a time, affected by torpor. Finally, it undergoes degeneration, and this pathological condition is expressed by the different qualitative changes of the galvanic reaction.

Very often, however, hyperæsthesia of the acoustic is not caused by anatomical changes in the different conducting structures, but is an idiopathic affection of the nervous apparatus itself.

HYPERÆSTHESIA WITH QUALITATIVE CHANGE OF FORMULA.

Hyperæsthesia of the acoustic nerve often occurs with morbid qualitative change in its reaction. Besides the reaction at KaC,KaD,AnO, acoustic sensations appear at AnC and AnD, sometimes even at KaO. In such cases, as a rule, the sensations at KaC, KaD, and AnO, exhibit the same definite character of sound, while those at

AnC, AnD, and KaO, bear the indefinite character of a murmur; though occasionally, with increased current-intensity, these latter also become well-marked sounds, but differing in character from the former. The following may serve as an example of hyperæsthesia with qualitative change of formula:

X250KaCS′
KaDS∞
KaOh (hissing)
AnCh
AnDh∞
AnOs>

The qualitative change of formula occurs sometimes without hyperæsthesia. This, together with hardness of hearing on the affected side, we often find as a symptom of facial paralysis.

HYPERÆSTHESIA WITH REVERSAL OF FORMULA.

Hyperæsthesia of very long standing may present the reversed formula; the acoustic then react-

ing only at KaO, AnC, and AnD. Such a formula is the following:

XV100KaC—
KaD—
KaOS>
AnCS′
AnDS∞
AnO—

In very inveterate cases of this kind the hyperæsthesia disappears, leaving only the reversion of the formula, both conditions expressing different degrees of degeneration of the acoustic nerve.

Hyperæsthesia with paradox—reaction of the unarmed ear is the most interesting form, and often occurs in very inveterate and incurable aural affections. On applying the electrode to one ear we obtain not only the acoustic reaction from this ear under the influence of the electrode, but also a reversed reaction from the other ear. Indeed, both acoustic nerves react at alternate moments, as if they were simultaneously treated with different electrodes. This paradox-reaction is accompanied

by a high degree of hyperæsthesia, and sometimes by the qualitative change of formula. The following may serve as an example:

Right ear (under the influence of the cathode).	*Left ear* (unarmed).
KaCS′	—
KaDS ∞	—
KaO—	s
AnC—	S′
AnD—	S∞
AnOS >	—

TORPOR OF THE ACOUSTIC NERVE.

This morbid condition is characterized by the enormously great current-intensities requisite for calling forth the acoustic reaction. Even twenty-five or thirty elements will produce no reaction, or a very slight one at KaC; and only repeated galvanic excitations may possibly produce very short acoustic sensations at KaD and AnO. The secondary and the tertiary excitability, if called forth at all, answer in a way scarcely perceptible. This torpor of the acoustic nerve to the galvanic

current is attended by a high degree of impairment of hearing.

TINNITUS AURIUM.

Abnormal reaction of the acoustic nerve, and especially hyperæsthesia, is almost always accompanied by morbid subjective acoustic sensations. This symptom, a real crux medicorum, impairs the functions of the brain, has a most depressing mental and moral influence upon the patient, and sometimes leads to suicide. The noises are located by the patient either in the ear or in the head, or sometimes in both. Very often two distinct noises are perceived simultaneously, or one noise is continuous, the other appearing at intervals. The patient complains of a constant heaviness in the head, and would be willing to bear forever the attendant hardness of hearing, if he could only be relieved from the distressing noises.

In simple hyperæsthesia these noises are instantaneously silenced by AnC and AnD, when the current is of sufficient intensity. This is still more easily accomplished, and with a smaller cur-

rent-intensity, when the current is suddenly reversed in the metallic part of the circuit from the cathode to the anode. To produce, however, a prolonged and permanent effect, it is necessary to avoid the reaction at KaC, KaD, and AnO, which is accomplished in the following way: The current is closed with the cathode at so low an intensity as not to excite the acoustic, and resistances in very small graduations are introduced into the rheostat until a certain intensity is reached, when suddenly the current is reversed to the anode. The acoustic is kept under the influence of the anode for a considerable time (half a minute or more); then, to avoid the AnO-reaction, the current intensity is imperceptibly diminished by gradually removing all the resistances from the accessory circuit. In this way the noises do not return after the opening of the current.

In other cases the noises are considerably kept down by AnC and AnD, but do not disappear altogether, though the patient feels much relieved and his hearing is ameliorated.

With the sudden cessation of the tinnitus, the

patients, astonished at the change, feel greatly relieved with their heads free and their hearing improved, and show a marked change in their coun tenances.

In cases of reversal of formula, the noises are checked by KaC, KaD, and AnO; while KaO, AnC, and AnD, either have no effect whatever upon the noises, or even increase them. Here we have to proceed in a manner exactly the reverse of that in the first form.

Where several noises coexist, it often happens that one is silenced by the current, while the other remains uninfluenced. The patients may say, for instance, that the noises in the head have entirely disappeared, but the noise in the ear persists.

Where we have tinnitus in conjunction with paradox-formula of the unarmed ear, the galvanization of one acoustic silences the noises in one ear, but, at the same time, calls forth the acoustic reaction in the other, and *vice versa*. Here we must divide the electrode that checks the noises in the treated ear, into two branches, dichotomously, placing one branch in each ear, while the indif-

ferent electrode, in the shape of a large plate, is applied, say, to the hand. As the branch in either ear is traversed only by half the current density, it is therefore necessary to use a stronger current.

GALVANIZATION OF THE ACOUSTIC NERVE IN DISEASED CONDITIONS.

The following cases will illustrate the treatment of aural affections by the galvanic current. Before narrating them, I may mention that those who have not witnessed the effects of the galvanization of the acoustic in diseased conditions cannot possibly have an idea of its beneficial influence, both upon the local affection and upon the general appearance of the patients. Even patients with the most inveterate, incurable aural affections almost always feel an immediate relief, and sometimes the effect is very striking. They invariably express astonishment and gratitude, and beg to let the current flow for the longest possible time.

The action of the galvanic current, in such cases, confirms the idea that the acoustic apparatus has a very great and direct influence upon the

brain. This has been demonstrated by physiological investigations, and especially by the latest and most beautiful experimental researches of Goltz. Already Flourens[1] had demonstrated that injuries of the labyrinth in animals produce vertigo and loss of equilibrium. Brown-Séquard has produced the same by section of the acoustic nerves. Goltz,[2] who had before shown that the central organ of equilibrium is situated in the corpora quadrigemina, has now given experimental proofs that the semicircular canals of the labyrinth are to be considered as the peripheric organ for the preservation of equilibrium.[3]

Exact clinical observations are in perfect accordance with these physiological experiments. Menière[4] has described cases where vertigo, vomit-

[1] Flourens, Recherches expérimentales sur les propriétés et les fonctions du système nerveux dans les animaux vertébrés. Seconde édition. Paris, 1842.

[2] Goltz, Ueber den Sitz der Seele des Frosches. Beiträge zur Lehre von den Functionen der Nervencentren, etc., Berlin, 1869, p. 52.

[3] Goltz, Ueber die physiologische Bedeutung der Bodengänge des Ohrlabyrinth's. Pflüger's Archiv, 1870, p. 172.

[4] Gazette Médicale de Paris, 1861.

ing, noises in the ears, appeared suddenly, simulating cerebral apoplexy, followed by unsteadiness in walking and standing, and by hardness of hearing, without any observable changes in the ear. The *post-mortem* examination could not detect any anatomical lesions in the brain and spinal cord, but only revealed effusion of lymph and blood in the semicircular canals of the labyrinth. A similar case, accompanied by complete deafness, after a fall upon the head, has been described by Politzer.[1] No changes could be detected in the external or middle ear, but, at the *post mortem*, an effusion of blood was found in the vestibule and semicircular canals. Troeltsch[2] also mentions that similar symptoms are often observed in diseases of the external and middle ear. Quite recently Voltolini and Reichel[3] have described the acute inflammation of the membranous labyrinth (otitis acuta intima) which often occurs in children, and presents all the symptoms of meningitis, under which

[1] Politzer, Archiv für Ohrenheilkunde, Bd. II., p. 88.

[2] Troeltsch, Lehrbuch der Ohrenheilkunde, 1868, p. 412.

[3] Berl. Klin. Woch., 1870, No. 24.

name it has been described by Moos and others. It must, however, be distinguished from the latter disease, as the labyrinth alone is affected, and not the meninges. It never terminates fatally, as meningitis often does, but is always followed by complete deafness. Children under seven years, of course, become deaf and dumb.

CASE I.—*Hyperæsthesia of the auditory nerve with tinnitus aurium. Catarrh of the middle ear. The noises cured by the galvanic current.*

Miss I. K., twenty-eight years old, was suffering from noises in the right ear, with hardness of hearing, in consequence of an inveterate catarrh of the middle ear. The tinnitus aurium and the attending dull headache increased during bad weather and every time the patient took cold. She had been treated several times here and in Europe, but the noises had not disappeared. The galvanic examination gave the following formula of simple hyperæsthesia:

X10KaC— (no reaction); the same with 20, 30, and 40 resistances of the rheostat.

X50KaCS
60KaCS′
KaDS ∞
KaO—
AnC—
AnD—
AnOS >

The noise disappeared suddenly and completely at the anodic closing.

The therapeutic application of the galvanic current I made in the following manner, November 20, 1868: the cathode being the ear-electrode, I gradually introduced resistances into the accessory circuit of 10 elements, beginning with 10, 20, 30, 40, and 50 resistances, when with the commutator I suddenly reversed the current to the anode. The patient immediately said that the noises in the treated ear had ceased. To be sure of this, I increased the resistances in the rheostat to 60, 70, 80, 90, and 100, allowing the current to flow uninterruptedly for half a minute, and then began gradually to remove them again.

At X90AnD—(no noises)

80AnD—

70AnD—

60AnD—

50AnD—

40AnD: A slight perception of noises. I again increased the resistance to 60.

60AnD—(no noises)

50AnD—

40AnD—

30AnD—

20AnD: A trace of noise was felt. I returned to 40.

40AnD—the noises disappeared again.

30AnD—

20AuD—

10AnD: The noises began to return.

30AnD—Again the noises have disappeared.

20AnD—

10AnD—

I let the current flow uninterruptedly for a minute, and then broke it, not, however, in the metallic part of the circuit, but to avoid the AnO-

reaction, by very slowly removing the electrode from the hand. The patient felt no noises until the next day, when the same treatment was repeated, but with a more lasting result—she had no noises for a whole week. I repeated the same operation once more, after which the noises did not return.

CASE II.—*Hyperæsthesia of the acoustic nerve, with noises in the head and ear, and headache. Deafness in the left ear, with anatomical lesions in the middle ear. Improvement of hearing, and rapid cure of noises in the head and of the headache, by the galvanic-current.*

W., thirty-four years old, deaf in his left ear from infancy; had typhoid fever a year ago, which left behind noises in the head and ear, hardness of hearing, and headache. Dr. Knapp sent him to me, with the following note: "Left membrana tympani degenerated and adherent to promontory, with extensive adhesions. Right membrana tympani depressed, handle drawn up and backward; catarrh of the middle ear cured, but no improvement of hearing and noises." I found a high de-

gree of hyperæsthesia. Under the influence of the anode the noises disappear completely, the patient exclaiming that his sight becomes clear, and his head quite free. Several days afterward he informed me that the headache had disappeared entirely, but the noise in the ear had returned, although in a very slight degree. I continue to treat the patient once a week; his hearing is normal; he has no headache, no noises in the head; and the noises in the ear are very slight, and disappear entirely after each galvanization.

In a similar way, and with the same result, I have treated several other cases of noises in the ear of very long standing, two of them originating from the use of quinine.

CASE III.—*Hyperæsthesia of the acoustic nerve; hardness of hearing of one ear, and deafness of the other. Headache and vertigo. Disappearance of all the morbid symptoms under the galvanic treatment.*

Miss R., aged thirty, teacher, daughter of a physician, was sent to me by Dr. Mussey, the distinguished professor of surgery in Cincinnati.

The patient is scrofulous, and both her parents, as well as her brother and sister, died of consumption. When in her seventh year she was attacked with a severe pain in the left ear, for the relief of which melted tallow was poured into the meatus as hot as it could be borne. The effect of this domestic remedy, as might have been expected, was extremely injurious; the pain was very much increased, and was followed by a purulent discharge. From that date there has been hardness of hearing, very frequently accompanied by tinnitus aurium, and purulent discharge from the left ear. In her seventeenth year the hardness of hearing was so much increased, that she was obliged to seek medical advice, from which unfortunately she derived no benefit, and, after a treatment of twelve months, her right ear also became affected with hardness of hearing, while the hearing of the left one was entirely lost. She could not hear an ordinary conversation, her head felt heavy, and she suffered from frequent headaches, vertigo, nervousness, and general debility.

The examination showed signs of previous

purulent inflammations of the middle ear; the left membrana tympani perforated. Politzer's experiment, used for some time, produced only a momentary improvement in the hearing, which immediately returned to its former condition.

The galvanic reaction of the acoustic nerve indicated simple hyperæsthesia.

Left ear.

X50KaCS′ (roaring of a cannon).

KaDS∞

KaO—

AnC—

And—

AnOS> (distant roaring of a cannon).

The right ear reacts with fifteen elements. AnC completely silences the noises.

After the first galvanic treatment, the patient experienced a great relief in the head and ears, and an irresistible inclination to sleep, so that she slept almost the whole of the day and night. The next morning she felt greatly invigorated, and her hearing very much improved. The same treatment was repeated the following day, viz.: the

acoustic reaction was called forth with the cathode, then the current was reversed with the commutator to the anode, and the ear kept under its influence for half a minute, after which, by means of the rheostat, the current-intensity was slowly and gradually decreased, and the circuit finally broken. The effect of this treatment was the same as after the first one. I repeated the treatment daily during one week, the patient feeling remarkably well, the heaviness of the head, the tinnitus aurium, and discharges from the ear, disappeared, the hearing became normal, and even the ear-wax, the secretion of which had entirely ceased for many years, returned.

The treatment could not be continued any longer, as the lady was obliged to leave New York, to resume her occupation in Washington.

CASE IV.—*Hyperæsthesia with paradox-reaction of the acoustic nerve. Loss of the olfactory sense. Tinnitus aurium, and hardness of hearing. No secretion of ear-wax. Return of the olfactory sense, and improvement of hearing, under the galvanic treatment.*

The following case is remarkable, and perhaps unique, with regard to the effect of the galvanic current upon the accompanying loss of the olfactory sense.

Mr. C. W., of New York, forty years old, and of good constitution, came under my treatment January 5, 1869. In his tenth year he had received a slap on the face, after which he experienced most excruciating pains, with subsequent discharge from the ears. Since that time he has been suffering from distressing noises in the ears and head, and hardness of hearing. His disposition was often very irritable, in consequence, as he thought, of extreme heaviness of his head. These symptoms become worse every time the weather is inclement, or whenever he contracts a bad cold. No secretion of ear-wax. The membrana tympani of both sides of an opaque white appearance, thickened, drawn in, without cone of light. He has entirely lost the olfactory sense for about twenty years. The galvanic reaction showed a high degree of hyperæsthesia of the acoustic, with paradox-reaction of the unarmed ear:

Right ear (under the influence of the cathode).		*Left ear* (unarmed).
X30KaCS′	very high ringing of a table-bell.	—
KaDS∞		—
KaO—		S
AnC—		S Ringing as on the right.
AnD—		S∞
AnOS>		—

Very small current-intensities, as well as any fluctuations of the current-density, gave the sound of a cithara-string. Anodic closing suddenly silenced the noises in the right ear, but provoked them in the left, and *vice versa*. Only the bifurcated anode, a branch of which was introduced into each ear, checked the noises altogether. Already, under the influence of the cathode, the patient had exclaimed, "I can smell odors." When the circuit was slowly opened, he felt his head quite free, as it had never been before, and said the galvanization had such a pleasant effect that he should like it to be continued all the while. The noises have returned, but in so slight a degree that they do not interfere with his disposition. After repeated treatment, his hearing has much

improved, and his olfactory sense is perfect. The secretion of ear-wax, that had ceased for many years, has reappeared, and he feels more life in the ear. While, before the galvanic treatment, every change of weather would aggravate his condition, now even a very bad cold has no influence upon his hearing.

CASE V.—*Tinnitus aurium, with two different noises, dizziness, and headache, for many years. Left acoustic affected with torpor, right hyperæsthetic, with reversal of formula. Deafness, with anatomical alterations in the auditory apparatus. Under the galvanic treatment, improvement of hearing, disappearance of dizziness and of one kind of noise.*

Mrs. McC., forty-two years old, mother of four children. Has several times had diphtheria of the pharynx. During the last ten years she has been suffering from continuous headache, with noises in the right ear. Left ear completely deaf; two large calcareous deposits in its membrana tympani. The hearing of the right ear so highly impaired that only very loud speech, close to the ear, can be heard; continuous noises; membrana

tympani opaque, perforated, the greatest part of it defective. Sight weak. She suffers very often from dizziness; these dizzy spells, as she calls them, lasting for several weeks, during which time she is unable to walk, and is obliged to lie in bed, as every attempt at getting up increases the vertigo. These, and other cerebral symptoms, aroused suspicion of an abscess or tumor in the brain. She had been treated repeatedly by most distinguished aurists, until her attending physician, Dr. Robert Newman, of New York, sent her to me for treatment by the galvanic current.

July 1, 1869, I found the left ear affected with torpor; 20 Siemens's elements, with exclusion of the rheostat, calling forth no acoustic reaction. Right ear hyperæsthetic, with reversion of formula; KaC, KaD, and AnO, remain without reaction; at the KaO, AnC, and AnD, two distinct noises, viz., roaring and bubbling (or boiling of a tea-kettle), which, at KaD, last indefinitely.

Immediately after the first application, the patient felt a great change; her head became free, her sight cleared and her general expression

improved. The galvanic treatment was at first employed twice a week, and afterward only occasionally. The improvement, both local and general, was rapid and astonishing. The headache and dizziness disappeared altogether. The bubbling, which was the most unpleasant of the two noises, has been entirely silenced by the cathode, and has not since returned; but the roaring continues, although in a very slight degree. The hearing has improved wonderfully, so that the lady is able to converse, and can hear such murmurs as, for instance, the scraping of a pen, etc., which formerly she could not at all perceive. Her general condition is very good; she is no longer anæmic; feels stronger, sleeps well, has a good appetite, and all other functions are normal.

I have had several cases with qualitative change of formula, two of which accompanied paralysis of the facial nerve.

Case VI.—*Facial paralysis of the right side. Hardness of hearing, with qualitative change of formula. Recovery.*

Mr. C. had contracted paralysis of the right

side of the face from a cold, and came under my treatment February 1, 1870. The muscles of the face exhibited considerable loss of farado-contractility, but increase of galvano-contractility. As there was also hardness of hearing on the affected side, I examined the acoustic apparatus with the galvanic current. I found that, besides the reaction at KaC, KaD, and AnO, the patient perceived a roaring at AnC, which would indefinitely last at AnD. The treatment consisted in the galvanization of the ear, so as to let the current penetrate in its full force at KaC and KaD, avoiding the anodic reaction by the usual manipulations. In the course of a month, the patient recovered from the paralysis and from the hardness of hearing, and the formula became normal.

I will mention here that an abnormal reaction of the acoustic nerve sometimes accompanies paralysis of the eye-muscles, and is, according to Brenner, a valuable symptom, and often the only one, indicating the central source of the paralysis.

I had several cases of hardness of hearing, with

torpor of the acoustic nerve, where galvanization of the ear resulted in a considerable improvement of hearing; for instance:

CASE VII.—*Torpor of the auditory nerve. Improvement of hearing, under the galvanic treatment.*

Mr. F., over sixty years old, has had impaired hearing from his childhood, and has been treated unsuccessfully here and in Europe. His left ear was already completely deaf, and for some years past the right had been gradually becoming so. He could hear only a very loud voice, and close to the ear; the ticking of a watch could not be heard at all. Twenty-five elements of Siemens produced no acoustic sensation, and only with thirty elements a slight and very short reaction was felt at the KaC, but none at the other moments of excitation. By repeated galvanizations of the ear, I succeeded in calling forth the acoustic reaction with twenty and even fewer elements, and a slight reaction at the KaD and AnO could be distinctly felt. At the same time the hearing considerably improved.

CASE VIII.—*Torpor of the acoustic nerve. Deafness. Restoration of hearing.*

About twelve years ago, Mr. A. D. detected dulness of hearing in right ear, which gradually increased to total deafness about two years since. Lately his left ear also began to fail, and, alarmed at the prospect of a complete deafness, he consulted several aural surgeons, whose examination always gave the same result.

On examining the ear, I was able to confirm the diagnosis that there were no anatomical lesions to be detected, and I noticed at the same time a very pale appearance of the walls of the meatus and of the tympanic membrane. I found no ear-wax, as its secretion had ceased for a great many years.

The galvanic reaction was as follows:

Right ear.

Twenty Siemens's elements, with the exclusion of the rheostat, gave no reaction. The same with 21, 22, 23, 25, 26.

XXX2100KaCsEI

XXX1100KaCSEII^{1000}

XXX800KaCSEIII^{1000,300}

Consequently torpor of the acoustic nerve.

The left ear reacts with 22 elements.

The treatment consisted in calling forth the normal formula in its three degrees of excitability. Immediately after the first treatment the patient stated that he could hear with the right ear loud conversation from a considerable distance. The tympanic membrane appeared of a scarlet color after the application. During the first fortnight of treatment the hearing continues to improve, although with less rapidity than could have been expected from the first experiment. The secretion of cerumen commences to reappear.

Similar cases of complete deafness of one ear, exhibiting no anatomical lesions, have been treated by me with a considerable improvement of hearing. I will mention the following case: A gentleman of New York lost the hearing of one ear while serving in the artillery during the war, in consequence, as he thinks, of the deafening effect the artillery-fire produced upon his auditory organ. After the galvanic treatment the patient could use his ear for ordinary conversation, and

hear the ticking of a watch at a distance of two feet.

As can be seen from the foregoing cases, to which I could add a considerable number of others, the treatment of affections of the acoustic nervous apparatus is accomplished by the same means by which they have been diagnosticated. Every unprejudiced observer will agree with the closing sentence of Brenner: "Henceforth a diseased ear cannot be considered fully examined, and the means for its cure exhausted, so long as for these purposes the galvanic current has not been used in a scientific manner."

II.

THE GALVANIC REACTION OF THE OPTIC NERVE.

As an appendix to the foregoing chapter, I will make a few remarks with regard to the galvanic reaction of the optic nerve. Already Volta had observed that the galvanic current produces a sensation of light. Pfaff, Ritter, and others, especially Purkinje, by numerous experiments upon themselves, have shown that, besides the flash of light, the galvanic current calls forth a perception of different colors, according to the direction of the current. Helmholtz[1] found that, under the influence of the cathode, objects are seen more clearly, and that the anode makes them appear darker and less distinct—a phenomenon which he ascribes to the increased or diminished irritability of the optic

[1] Handbuch der physiologischen Optik. Leipzig, 1867, p. 204.

nerve in the catelectrotonic and anelectrotonic states. The current, passing the optic nerve in an ascending direction, calls forth the perception of a bluish color, which yields to a reddish-yellow color after the breaking of the current. In the opposite (descending) direction of the current, the field of vision is of a reddish-yellow color, the entrance of the optic nerve alone being marked by a blue circle; at the breaking of the current, the field of vision becomes again blue, and the entrance of the optic appears dark.

Brenner [1] has shown that the optic reacts to the galvanic current with two colors simultaneously. Under the influence of the cathode, a blue centre is perceived surrounded by a yellowish-green color; at the cathodic opening, on the contrary, the centre is yellowish-green, and the periphery blue. At the anodic closing, the centre is yellowish-green and the periphery blue; and, at AnO, centre blue, periphery yellowish-green.

I have observed that, in some persons, and especially in some diseased conditions of the optic,

[1] *Op. cit.*, p. 73.

the galvanic current will call forth only flashes of light, and scarcely any perception of colors; in others, the contrary takes place. The two following cases are especially interesting with regard to this phenomenon:

A patient, affected with paralysis of the left nervous oculomotorius and abducens, had been treated in the German Dispensary for more than three months, but without any change. I began to treat him with the galvanic current, under the influence of which a rapid change for the better took place. But the point of interest in the case was that the weakest currents, of two elements of Siemens, for instance, applied to any part of the head, would produce a distinct perception of color —under the influence of the cathode a beautiful blue, and under that of the anode a violet. But even the highest current-intensities, that can safely be applied to the head, would not produce a flash of light.

Another patient, sent to me by Dr. Althof, and suffering probably from a neuralgic affection of the ciliary nerves, presented exactly the reverse

condition. The weakest current passed through the head, as well as the smallest fluctuations of the current-density, would invariably produce intense flashes of light, but no perception of color could be called forth with any current-intensity in either direction.

I think that these observations, which have not yet been mentioned by any other writer, corroborate Max Schultze's theory with regard to the function of the rods and cones of the retina.[1] Basing himself upon exact anatomical and physiological researches in different classes of animals, he gave an ingenious hypothesis, according to which the rods serve for the perception of light only, and the cones for the perception of colors. From the galvanic reaction of the optic apparatus I am also inclined to admit the view of distinct functions for each of these structures.

The application of the galvanic current has, of course, been found of great efficacy, in paralytic conditions of the eye-muscles. Judging from anal-

[1] Max Schultze, Zur Anatomie und Physiologie der Retina. Archiv für microsk. Anatomie, Bd. ii., p. 165.

ogy in other nervous diseases, it must also be very efficient in the treatment of affections of the nervous apparatus of the eye.

The earliest record of the successful use of the galvanic current in amaurosis dates as far back as 1801. The celebrated anatomist Loder, of Jena, on the advice of Alexander von Humboldt, to whom he gave instruction in anatomy, instituted experiments on patients of his clinic. He describes, in his "Journal of Surgery," two authentic cases of amaurosis cured with the galvanic current by Lichtenstein and Bischoff, and witnessed by himself.[1] Of recent observers I will mention Remak, who was able to convince himself and Graefe of the beneficial effect of the galvanic current, in some affections of the retina.[2]

I myself treated a patient who had been examined by Prof. Graefe. He was affected with retinitis pigmentosa; his sight was much impaired, and his field of vision greatly reduced, so that he

[1] Vide Remak, Galvanotherapie der Nerven und Muskelkrankheiten, p. 151.

[2] *Op. cit.*, p. 460.

could not read, or cross the street without assistance. I treated him with the galvanic current at different times within a year, and, though his retinitis pigmentosa remains in the same condition, yet his sight has wonderfully improved; he can not only walk alone, but reads many hours every day without the least inconvenience.

It would certainly be worth while to try the effect of the galvanic current in such affections of the nervous apparatus of the eye as are yet considered incurable, especially in incipient amaurosis. But for that purpose it will be necessary to combine the scientific use of the galvanic current with the exact diagnosis made by experienced and learned oculists.

III.

THE ACTION OF THE GALVANIC CURRENT UPON THE SYMPATHETIC NERVE.[1]

GRIESINGER, a high authority in medicine, and principally in the domain of nervous diseases, says: "Electro-therapeutics with its rapid progress is bringing the sympathetic, in a way never before expected, into the sphere of action of its invaluable agent—the galvanic current."[2] Indeed, the galvanization of the sympathetic, introduced by Remak, is one of the greatest therapeutic discoveries of our century. My own experience daily convinces me of the important part which the galvanization of the sympathetic plays in electro-therapeutics.

[1] This paper was read before the New York County Medical Society, June 6, 1870.

[2] Griesinger's Archiv für Psychiatrie und Nervenkrankheiten, Bd. i., Heft ii., p. 420.

It is easy to explain the effect of the galvanization of the sympathetic, when the large number of its vasomotor nerves, and the great influence of the circulation upon the functions of an organ, are taken into consideration. The important influence the condition of the blood-vessels exercises upon the brain is well known, and, as Benedikt justly remarks, the brain is healthy so far as its vessels are healthy, and its functions are normal if its vasomotor nerves act normally.[1]

Benedikt advises to galvanize the cervical sympathetic by applying the electrodes over its superior and inferior ganglia, sending the current in an ascending or a descending direction, either on both sides or only on the affected side. A sensitive spot, generally corresponding to the upper ganglion, is often detected, the galvanization of which is almost always followed by a surprising result. A stronger pulsation of the carotid is then observed.

The sympathetic must be very cautiously galvanized with a weak current and not longer than

[1] Benedikt, Electro-therapie. Wien, 1868, p. 87.

half a minute, or else dangerous cerebral symptoms may be produced: vertigo, congestion, hemorrhage, convulsions, etc. In some particular cases, however, the galvanization may be prolonged for several minutes.

With regard to vertigo, I will mention here that the application of the electrode to the fossa auriculo-maxillaris calls forth vertigo with loss of equilibrium and nausea. Remak[1] ascribes this phenomenon to the change of equilibrium between the two parts of the cerebellum, produced by the excitation of some fasciculi of the superior ganglion of the cervical sympathetic of one side.

The thoracic and abdominal ganglia of the sympathetic are galvanized, according to Benedikt,[2] by applying one electrode to the inferior cervical ganglion and the other to the sides of the lumbar vertebræ.

Moritz Meyer[3] has lately published authentic cases of paralysis, progressive muscular atrophy,

[1] Remak, Application du Courant Constant, etc., p. 7.

[2] Benedikt, *op. cit.*, p. 88.

[3] Moritz Meyer, Therapeutische Erfolge der Galvanization des Sympathicus. Berl. Klin. Wochenschr., 1870, No. 22.

vasomotor spasm, arthritis nodosa, cured by galvanization of the sympathetic, without the use of any other medicinal remedies. He adheres to the following method: he places the cathode of a current, generated by twelve or eighteen Siemens's elements, over the superior ganglion of the cervical sympathetic (on the affected side), and the anode over the transverse process of the seventh cervical vertebra on the opposite side. The current is allowed to flow in this direction for five or ten minutes, when the following phenomena manifest themselves:

1. A sensation of heat, with a real increase of temperature, demonstrable by the thermometer, in the arm corresponding to the cathode.

2. The fingers and palm of the hand become covered with perspiration.

3. At the same time cessation of the existing spasm, or of the neuralgic pain and tension, and a sensation of relief in the affected extremity.

I often galvanize the sympathetic by the polar method.

That the galvanic current really affects the

sympathetic can be concluded from the fact that it produces symptoms analogous to those produced by the direct irritation or section of the sympathetic in animals, and especially in the condition of the pupils and in the modified circulation and temperature. Nevertheless, the possibility of the galvanic current penetrating to the sympathetic in the uninjured living subject was always doubted by physicians, and Ziemssen,[1] even in the last edition of his excellent work on Electro-therapeutics, still denies it.

I therefore undertook to examine it by direct experiment. Through an incision in the skin of a rabbit I introduced to the cervical sympathetic the nerve of a galvanoscopic frog, and succeeded, although with great difficulty, in bringing a small portion of the nerve in contact with the sympathetic, the rest of the galvanoscopic leg being carefully isolated. It was necessary, for that purpose, to remove portions of the pneumogastric nerve and of other structures. After closing the wound

[1] Ziemssen, die Electricität in der Medecin, 3. Aufl. Berlin, 1866, p. 68, *et seq.*

and applying the electrodes to the skin, I let a current of twenty or thirty Siemens's elements pass in the direction of the sympathetic. At the closing of the current as well as at its breaking, reversing and sudden fluctuations of its density, the galvanoscopic leg exhibited vivid contractions.

To enable us to judge of the alterations that take place in the sphere of the sympathetic, the following physiological and pathological facts may be briefly enumerated:

The nerves distributed in the viscera and vessels are generally called nerves of the sympathetic, the origin of which is not yet fully demonstrated. In accordance with anatomical and physiological facts, the numerous ganglionic cells, aggregated in the large cavities or disseminated in the parenchyma of the viscera, must be considered as the central organs of the sympathetic. The nerves of the sympathetic are connected with the cerebrospinal system, but not with the volitional organs, all the movements of the viscera being perfectly involuntary. These nerves do not contain sensitive fibres, and the sensibility of the viscera is prob-

ably conducted by the medullary (myelinic) cerebrospinal nerve-fibres. All the smooth (unstriped) muscular fibres are controlled by the sympathetic.

The functions of the central organs of the sympathetic are of an automatic or reflex nature.

Some viscera (heart, stomach, intestines, etc.) contain within their substance ganglia which control their functions. The automatic rhythmic action of the heart, for instance, depends upon such ganglionic cells, but this automaty is at the same time influenced by moderating (inhibitory) and accelerating nerves, both originating from the cerebro-spinal organ. The inhibitory fibres are contained in the pneumogastric, and the accelerating in the sympathetic (in the inferior cervical and superior thoracic ganglia). The normal stimulus for this automatic function of the heart is oxygen (of the blood), while the stimulus for its inhibitory nervous apparatus is carbonic acid.

The automatic peristaltic movement of the intestinal canal is also dependent upon the ganglionic cells situated within the substance of these viscera, and is controlled by an inhibitory nerve

(the splanchnic), and by accelerating nerves from the abdominal plexuses of the sympathetic.

The cervical part of the sympathetic contains:

1. Vasomotor fibres for the corresponding side of the head, the origin of which is in the cerebro-spinal organ.

2. Nerve-fibres for the dilatator pupillæ, originating also in the cerebro-spinal organ.

3. Secretory nerve-fibres for the salivary and lachrymal glands.

4. Accelerating nerve-fibres for the heart (Bezold).

5. Nerve-fibres passing to the cerebro-spinal organ for the excitation of the inhibitory apparatus of the heart and for the excitation of the vasomotor centre.

The most important nerves that originate from the thoracic part of the sympathetic are the splanchnic nerves, which contain:

1. Inhibitory and accelerating nerve-fibres for the intestinal canal.

2. Vasomotor nerve-fibres for the large vascular territory of the abdomen.

3. Secretory fibres for the kidneys.

4. Centripetal nerve-fibres, moderating, by reflex action, the pulsations of the heart.

5. Nerve-fibres, the excitation of which is followed by the presence of sugar in the urine.

In regard to the abdominal part of the sympathetic, our knowledge is yet very incomplete. It has been ascertained that irritation of the abdominal sympathetic and of the different plexuses (cœliacus, mesenterici, renalis, suprarenalis, spermaticus, hypogastrici) calls forth or increases the contractions of the adjacent organs; of the intestines, bladder, ureters, uterus, vesiculæ seminales, spleen. On the other hand, section or extirpation of the abdominal sympathetic and plexuses produces disturbances in the circulation and nutrition of the abdominal organs.

The contractions of the uterus are called forth by irritating the hypogastric plexus, and also the spinal cord as far as the cerebellum.[1]

Pourfour du Petit demonstrated that sec-

[1] Vide Hermann: Grundriss der Physiologie des Menschen. Berlin, 1870, p. 443, *et seq.*

tion of the cervical sympathetic produces contraction of the pupil, diminution of the eyeball, redness and increased secretion of the conjunctiva; while irritation of the sympathetic, on the contrary, produces dilatation of the pupil. Claude Bernard[1] has confirmed the correctness of these experiments, and has shown, besides, that section of the cervical sympathetic in animals produces dilatation of the small arteries on the corresponding side of the head, accompanied with increased temperature and increased secretion on the same side. Bernard has further shown that electrical irritation of the upper end of the cervical sympathetic calls forth the reversed condition; the pupil dilates, the eyeball protrudes, the temperature sinks below the normal, and the conjunctiva and ear become pale. Remak[2] has found experimentally that the sympathetic has a direct influence on some voluntary muscles. He has shown that section of the cervical sympathetic, besides the above-described symptoms, produces relaxation of the

[1] Gazette Médicale de Paris, 1852, p. 75.

[2] Deutsche Klinik, 1859, p. 294

levator palpebræ superioris, and spasmodic contraction of the orbicularis (ptosis, with lifting of the lower lid); electrical irritation of the lower end of the cervical sympathetic opens the eye. Heinrich Müller[1] discovered a smooth (unstriped) muscle, the orbital muscle, the contraction of which protrudes the eyeball. This can be produced in animals by irritating the cervical sympathetic. Prussak,[2] on irritating the cervical sympathetic in living animals, observed the contraction of blood-vessels in the walls of the tympanic cavity. Morcau[3] discovered the important influence of the sympathetic upon the functions of the intestinal canal by an experiment, which seems to throw some light upon the action of drastic medicines. After section of the mesenteric nerves, he invariably found the corresponding portion of the intestinal canal filled with fluid. This fluid undoubtedly transuded from the dilated vessels in conse-

[1] H. Müller, Verhandl. der Phys. Med. Gesellschaft in Würzburg. 1859. Bd. 9, p. 76.

[2] C. Ludwig, Arbeiten aus der Physiolog. Anstalt zu Leipzig, 1868, p. 86.

[3] A. Moreau, Centralbl. f. d. Med. Wiss., 1868, No. 14.

quence of the paralytic condition of their vaso-motor nerves, as it contained urea and but little albumen.

Phenomena similar to the above enumerated are often met with in man in some diseased conditions, and correspond therefore to section (paralysis) or to irritation of the sympathetic. Moreover, they can be called forth by the galvanic current. Eulenberg and Schmidt[1] have experimented on the living man, and demonstrated that, by applying the electrodes of a galvanic current to the places corresponding to the upper and lower ganglia of the cervical sympathetic of one side, either dilatation or contraction of the pupil of the same side is produced, according to the direction of the current. They have also observed, during and after galvanization of the sympathetic, a considerable diminution of the pulsations of the heart, with diminished pressure in the arteries. These experiments were made in a very exact manner, with the aid of the pupilloscope, sphygmograph, etc. I have several times myself seen, and it has been described by

[1] Centralbl. für d. Med. Wissensch., 1868, Nos. 21 and 22.

different authors (Villebrandt, Gairdner, Ogle, Verneuil, and others), a constant contraction of the pupil on the side where pressure has been produced on the cervical sympathetic by an aneurism of the aorta or innominata, or by other tumors.

This contraction of the pupil has often been accompanied by congestion and increased secretions on the corresponding side. Again, Demme has described a case of goitre with dilatation of the pupil and protrusion of the eyeball, phenomena corresponding to irritation of the cervical sympathetic. A very interesting case of this kind has been described by S. Weir Mitchell, George R. Morehouse, and William Keene.[1] The right cervical sympathetic had been injured by a ball, in consequence of which followed contraction of the right pupil, ptosis on the right side, apparent shrinking of the right eyeball, redness of the conjunctiva, epiphora, and myopia, pain in the frontal region, especially in the right eye, and weakness of memory. The right half of the face was unu-

[1] Gunshot Wounds and Other Injuries of Nerves. Philadelphia, 1864, p. 39.

sually red, the left rather pale. After five months the patient could resume his usual occupation, the contusion of the sympathetic, evidently caused by the projectile, having healed. This case presented all the phenomena which are observed in animals with an injured cervical sympathetic. They can be explained by the paralytic condition of the vaso-motor nerve-fibres contained in the cervical sympathetic and distributed in the first branch of the fifth pair, and by the consequent relaxation and dilatation of the small cerebral blood-vessels. The ptosis and apparent smallness of the right eye are explained by the abolished function of the muscles, the innervation of which proceeds from the sympathetic.

But even more than the physiological and pathological facts, the therapeutic success following the galvanization of the sympathetic, especially in neuralgic affections, and the cerebral symptoms it manifestly calls forth, will convince every observer of the possibility of galvanizing the sympathetic in the living man, and of its high importance in electro-therapeutics.

Through the vasomotor nerves contained in the track of the sympathetic, we are enabled to influence the circulation in diseased organs, and consequently to modify their nutrition. Remak ascribes the absorption of exudations to the property of the vessels to contract and dilate under the influence of the galvanic current.

The central organ of the vasomotor nerves is in the medulla oblongata, the irritation of which produces contraction of all the small arteries, and therefore increase of blood-pressure in the arterial trunks and overfilling and distention of the heart (Ludwig and Thiry). This centre is continually kept in activity by the exciting influence of the carbonic acid of the circulating blood, and this explains the persistent tone of the vasomotor nerves. Section of the cervical spinal cord abolishes this tone. Cyon and Ludwig have discovered a moderating or inhibitory nerve for the vasomotor centre, called nervous depressor. Its irritation produces paralysis of all the small arteries, which become distended and filled with blood, leaving the heart almost empty.

From the vasomotor centre nerve-fibres pass through the spinal cord to the sympathetic and thence to the arteries. Therefore, section of the spinal cord causes dilatation of all the arteries receiving their nerves below the section, while irritation of the spinal cord, on the contrary, produces narrowing of the corresponding arteries. The vaso-motor nerves for the head accompany the cervical sympathetic (Bernard), and for the lower extremities the anterior roots of the spinal nerves (Pflüger), which they enter with the rami communicantes of the sympathetic. The vasomotor nerves for the upper extremities enter with the rami communicantes the brachial plexus (Cyon).

The principal vasomotor nerves are the splanchnic, the irritation of which produces the contrary effect to the irritation of the depressor, namely, general contraction of the peripheric arteries and overfilling of the heart; their section produces dilatation of the small arterics.

By galvanization of the cervical sympathetic we may produce hyperæmia or anæmia in the

medulla oblongata, and in the vasomotor and other centres there situated. We may also produce these conditions in the different centres of the brain, for instance in Setschenow's centre (the inhibitory centre of reflex action of the spinal cord),[1] in Nothnagel's convulsive centre (pons varolii),[2] and consequently prevent or call forth epileptic attacks and other cerebral disorders.

GALVANIZATION OF THE SPLANCHNIC NERVES.

Two cases which I have had recently under observation have convinced me that by means of the galvanic current we are able to exercise a direct influence on the splanchnic nerves—the most powerful vasomotor nerves. In a very robust patient I applied the anode of fifteen elements of Siemens to the thoracic part of the spinal cord, and the cathode to the prostatic part of the urethra. In less than half a minute the face and the whole

[1] Setschenow, Hemmungsmechanismen für die Reflexthätigkeit des Rückenmarks. Berlin, 1863.

[2] Nothnagel, Enstehung Algemeiner Convulsionen in Virchow's Archiv, Bd. 44, Hft. I.

surface of the body assumed a death-like pallor, from the tetanic contraction of all the small arteries, and this was followed instantly by syncope. Another patient, also very robust, presented precisely the same phenomena when the anode of twenty-five elements was applied to the same place as in the former case, and the cathode to the hypogastric region.

GALVANIZATION OF THE SPLANCHNIC IN CERTAIN FORMS OF EPILEPSY.

The vascular territory controlled by the splanchnic nerves is so large that it can contain almost all the blood of the body. Ligation of the portal vein in animals therefore produces death from acute anæmia, as the whole amount of blood remains in the visceral vessels (Ludwig and Thiry). On the other hand, the arterial blood-pressure increases enormously with the sudden contraction of the abdominal vessels. This contraction can be produced, for instance, by the action of cold through the stomach, and explains,

according to Hermann,[1] the great danger of taking a cold drink when the blood-pressure is already increased, as after muscular exercise, etc., especially in a diseased condition of the vessels.

The following case, which I have recently observed, and of which I shall give the details in another place, when treating of epilepsy, seems to me of the utmost practical importance, as it opens a new field for the successful treatment of a most dreadful disease.

Case IX.—*Epilepsy with aura in the epigastric region. Galvanization of the splanchnics. Improvement.*

A. M., of New York, aged seven, after a severe diphtheria when one year old, was attacked with epilepsy. The paroxysms at first appeared but once a year, then every month, and afterward quite frequently. Besides these great attacks, he had several times a day (occasionally eleven times) fits of *petit mal*.

The parents had consulted several eminent

[1] L. Hermann, Über die Gefahren deskalten Trunkes bei erhitztem Körper. Pflüger's Archiv, III., 1–46.

physicians in this country and abroad, among them Brown-Séquard. This great physiologist and neuropathologist pointed out, as of great importance, the aura which invariably precedes every attack. The little patient always grasps with both hands at the epigastric region, where he feels a sudden pain, accompanied by an unpleasant sensation in the head and pallor of the face, immediately after which the epileptic fit follows. Notwithstanding the different methods of treatment during six years, the epileptic attacks continued, and the child finally presented a considerable degree of idiocy, associated with general debility and anæmia.

I began at once the galvanization of the splanchnic nerves twice a week, and it was followed by a marked beneficial effect. From the very first day, the child has not had a single attack of epilepsy, and the *petit mal*, which, before the treatment, occurred many times every day, appears about once a week, and so slightly that it is scarcely noticeable. For the last fortnight he has not had it at all. The general condition has

undergone a most remarkable change. The child has a healthy appearance, his intellect is brighter, and his disposition, formerly extremely irritable and unmanageable, is now becoming quiet and orderly.

In this case I explain the origin of the epileptic attacks and the beneficial effect of the galvanization of the splanchnic nerves in the following manner: From some unknown cause, all the visceral vessels, under the command of the splanchnic nerves, suddenly become dilated and filled with blood, which causes acute anæmia of the brain, as indicated by the pallor of the face and of the whole body, and which, according to Kussmaul and Tenner, calls forth epileptic convulsions. Or, perhaps, under these circumstances the pons varolii (Nothnagel's convulsive centre) undergoes an irritation from the accumulated carbonic acid, and reacts with general convulsions.

In this particular case I galvanize the splanchnic in the reverse manner to the one which, as experience has taught me, produces general anæmia, and thus prevent the epileptic attacks.

THE GALVANIZATION OF THE SPLANCHNIC IN DYSMENORRHŒA.

I have found the galvanization of the splanchnic of the greatest value in dysmenorrhœa, and give here an abstract of the following case, which will be fully related in another place.

CASE X.—*Dysmenorrhœa with profuse menstruation. Galvanization of the splanchnic. Disappearance of all morbid symptoms.*

Mrs. P., of Boston, aged twenty-four, married six years, but sterile, suffers from dysmenorrhœa in its intensest degree. She has been treated by most eminent gynæcologists with sponge-tents and other local and constitutional remedies, without any benefit. Last year the incision of neck of the uterus was performed, and, instead of giving relief, it seemed to have aggravated all the morbid symptoms. The menstruation continued to be as painful as before, and still more profuse; she suffered a great deal from headache, want of sleep, and dyspepsia, from agonizing pains in the back, and especially in the region of the left ovary.

August 22d, a few days before the expected menstruation, I proceeded to galvanize the splanchnic, which was followed by an immediate beneficial effect. The headache and pains in the back disappeared; she slept through the night better than she had for many years, and the next day felt refreshed and stronger, and had a good appetite. I repeated the galvanization of the splanchnic on the following three days, after which the menstruation appeared perfectly painless. While, on all former occasions, the patient was obliged to keep her bed during the whole period of menstruation, losing a great amount of blood and suffering from most excruciating pains, this time the menstruation was normal in all respects, painless, and allowed her to be up all the time.

I have treated several other cases of severe dysmenorrhœa by the same method and with the same result, and can therefore recommend it to the consideration of gynæcologists.

According to Benedikt,[1] the great success following the galvanization of the sympathetic, in

[1] Benedikt, *op. cit.*, 253.

encephalic diseases, must be ascribed to its curing the disorder of the sympathetic. He also ascribes the symptomatic optic neuritis to an affection of the vasomotor nerves, and thus explains the excellent result we obtain from the galvanic treatment. This last assumption, however, is not in accordance with the majority of cases. Optic neuritis, which is of high importance for the diagnosis of pathological conditions of the brain, often accompanies different intracranial affections. There are two kinds of neuritis of the optic nerve which can be distinguished by ophthalmoscopic examination. Optic neuritis is sometimes caused by the continuation of basilar meningitis along the optic trunk to the eye (neuritis descendens); much oftener, however, the neuritis is not the consequence of basilar meningitis, and does not affect the nerve-trunk at all, but only the intra-ocular end of the optic nerve. This optic neuritis invariably accompanies increased pressure within the cranial cavity, caused by intra-cranial tumors. Graefe explains this kind of optic neuritis by the increased cerebral pressure being an obstacle to the free reflux of

blood from the orbit into the cavernous sinus, and by a consecutive serous exudation in the region of the ophthalmic vein.

Schmidt[1] explains the optic neuritis attending increased intra-cranial pressure by the communication which exists between the arachnoidal space and the lymphatic spaces of the eye discovered by Schwalbe.[2] According to Schmidt, the increased pressure in the cranial cavity sends the fluid from the arachnoidal space into the space between the nerve-sheaths and into the lamina cribrosa, which latter strangulates the intra-ocular end of the optic nerve, and produces the swelling of its papilla.

According to Allbutt,[3] optic neuritis, both in the chronic and in the acute form, often accompanies diseases and injuries of the spinal cord.

As practical illustrations of the great value of the galvanization of the sympathetic, I will give only two of a great many cases from my own practice.

[1] Archiv für Ophthalm., xv., 2, p. 193.

[2] Centralbl. für die Med. Wissensch., 1869, No. 30.

[3] On the Ophthalmoscopic Signs of Spinal Disease. Lancet, January 15, 1870, p. 76.

CASE XI.—*Epilepsy. Galvanization of the Sympathetic. Cure.*

Mr. L., of New York, a married gentleman, forty years old, of a healthy constitution and well nourished, had been suffering for three years with the following symptoms: Epileptic attacks, with complete loss of consciousness; an intense headache with which he awakens, and which lasts without a moment's suspense for the whole day, especially increasing about eleven o'clock and toward evening, and extending over the whole head. He could not read at all, being unable to distinguish the letters, and presented a high degree of amblyopia. It was impossible for him to express his ideas, for his memory failed him every time he attempted to speak, and he could not find the necessary words. This latter symptom extremely annoyed him, for he felt himself quite helpless, except for the assistance of his wife and daughter. His family and the patient himself expected insanity, because for the last few years his intellect had been steadily giving way, unfitting him to pursue his ordinary vocation. He had been unsuccessfully

treated by several physicians, until Dr. Ceccarini, of New York, sent him to me, October 11, 1868. My first impression with regard to the prognosis was very unfavorable: there was evidently some important affection of the brain, some kind of aphasia. The ophthalmoscopic examination revealed optic neuritis. I began to treat the brain with the galvanic current, but without any particular result, his condition remaining the same during a fortnight, and the epileptic attacks appearing rather oftener and severer. I then proceeded to the galvanization of the sympathetic, when soon no trace of the disease remained, and on the 20th of December, 1868, the treatment was at an end. The headache had entirely disappeared, the patient reads and expresses himself perfectly well, and has not had a single epileptic attack since. He is quite healthy, his sight is perfect, and he has long ago resumed his occupation as before the disease.

CASE XII.—*Paralysis. Galvanization of the sympathetic. Rapid improvement.*

Mr. W. M., about sixty years old, came under

my treatment on the 24th of August, 1868, affected with right hemiplegia, and paralysis of the left side of the face and tongue, in consequence of an apoplectic attack which had happened ten months before. He had been treated since the attack, but his paralytic condition remained the same. Galvanization of the brain, during the first week of my treatment, produced but a slight improvement, while galvanization of the sympathetic was immediately followed by an evidently beneficial effect. After a few applications, the facial paralysis had considerably diminished, he was able to speak better, to dress himself, lift his arm, and walk without crutches, although with some difficulty.

The following two cases have been treated by Remak in the presence of a committee of the Academies of Science and of Medicine in Paris.[1]

A young man, twenty years old, entered Velpeau's clinic three months after he had suddenly fainted. A fortnight after the first syncope a

[1] Application du courant constant au traitement des nevroses, p. 33, *et seq.*

second one had taken place, leaving a complete paralysis of the lower extremities, which, notwithstanding the use of different remedies, still remained. "When I first saw the young man," says Remak, "he could not stand without assistance, he walked with the greatest difficulty, dragging his legs, quite unable to bend the knees. The sensibility from the last rib to the feet was abolished; the legs could be pinched without producing the slightest sensation. This case being treated in the presence of the committee, it was essential that the effect should be prompt. According to my former experience, therefore, I applied the electrodes to the inferior ganglia of the cervical sympathetic, using for twelve minutes the current of twenty to thirty elements. The effect was immediate and surprising. The patient was able not only to lift his legs when standing, but he could climb upon a chair, and, though with a certain uneasiness, he could bend the knees in walking. And, what is still more important, the sensibility in the lower extremities was almost entirely restored. These facts were ascertained, the day previous to and

after the treatment, by a large number of physicians who examined the patient. I mentioned, to the numerous physicians present, that it was the application of the current to the inferior ganglia of the cervical sympathetic that in my opinion greatly contributed to this sudden change. On again applying the constant current for three minutes, the patient climbed upon the chair with the greatest ease; and after the third application he was quite cured, and since then has had no relapse. As to the nature of the disease," continues Remak, "I believe it to have been a particular kind of epilepsy, which, on the subsequent narrowing of blood-vessels at the base of the brain and in the medulla oblongata, left this anæsthetic paraplegia. It is therefore evident why, on the application of the current to the cervical part of the sympathetic, the morbid symptoms suddenly disappeared. Had not the patient been rapidly restored, atrophy of the nervous centre would have been produced, followed by an absolutely incurable paraplegia. By an analogous process we succeed in improving and often in entirely curing epilepsy."

The next is a case of hysterical (reflex) paralysis: "A lady, thirty-six years old, suffering for a long time from prolapsus uteri, was paralyzed, could scarcely walk a few steps, and would fall on closing the eyes. The application of the constant current, repeated several times, to the lumbar region and solar plexus, produced a very rapid effect. Her gait improved; she could mount the chair without any assistance, and could stand steady with her eyes closed. The uterus, as I had predicted," continues Remak, "has returned to its normal position—the effect of the current upon the unstriped muscular fibres of the broad ligaments."

The following case of arthritis nodosa, lately related by Dr. Moritz Meyer,[1] is one of many others he has successfully treated by galvanization of the sympathetic, according to his method already mentioned, and without the use of any medicine: The patient, a lady aged twenty-four, anæmic in the highest degree, suffered since 1869 from swellings of almost all the joints of the upper and lower ex-

[1] Berliner Klinische Wochenschrift, 1870, No. 22.

tremities. The joints were almost immovable and extremely painful, especially at night and in bad weather. The appetite and digestion deranged, the menstruation scarce, and the pulse small and accelerated. After having been unsuccessfully treated with internal and external remedies and different mineral waters, she came under Dr. Meyer's care, who at once proceeded to the galvanization of the sympathetic, according to his method. From the very first treatment a decided improvement was evident. The pains disappeared, the swellings diminished, the temperature of the extremities increased, and the hands became covered with profuse perspiration. After thirty-three sittings the patient could walk a whole hour, the pain and swellings of the lower extremities having entirely disappeared. At the same time the urine became abundant, of high specific gravity, with a large sediment of urates, and the perspiration of a penetrating odor. After seventy-five treatments the patient had entirely recovered, her complexion is healthy, her appetite and digestion excellent, and all the secretions normal.

In conclusion, I will give a brief account of some diseases which at present are considered as caused by an affection of the sympathetic, and in which the galvanization of the sympathetic is followed by a beneficial effect.[1]

HEMICRANIA (MIGRAINE, SICK-HEADACHE, NERVOUS HEADACHE).

Until lately, hemicrania has been generally considered as a neuralgic affection of the fifth pair (its first branch), but Romberg excluded it from the peripheric neuralgias and called it cerebral neuralgia. The real nature of hemicrania, however, was first discovered by Du Bois-Reymond,[2] who, being himself a sufferer from it, explained the observed phenomena as follows: All the symptoms of migraine (at least in his case) must be attributed to tetanus of the vasomotor nerves of the affected side of the head. He observed that, during the paroxysm, the temporal artery of the af-

[1] Eulenburg and Guttman, Die Pathologie des Sympathicus, Griesinger's Archiv, Bd. I., Heft 2, p. 420.

[2] Zur Kentniss der Hemicrania, Arch. f. Anat. und Phys., 1860, p. 461.

fected (right) side was felt resistant and contracted, while on the left side the artery remained normal. The face was pale and collapsed, and the right eye smaller and red. At the end of the paroxysm the right ear became red, with a sensation of increased temperature. The most pathognomonic phenomenon, which, more than any other symptom, could reveal the nature of the disease, was the dilatation of the pupil on the affected side, which Du Bois-Reymond observed during the paroxysms. These phenomena, the contracted condition of the temporal artery, the anæmic condition of the face, denote a prolonged tetanus of the muscles of the vessels of the affected side. After cessation of the tetanus of the vasomotor nerves, the over-fatigued muscular fibres of the vessels become relaxed and the vessels dilated, hence the redness and increased temperature at the end of the paroxysm. Such a tetanic contraction of the muscles of all the vessels of one half of the head must necessarily have its cause, according to physiological experiments, in the sympathetic of the same side, or in the corresponding side of the vasomotor centre

(centrum cilio-spinale), an assumption fully corroborated by the dilatation of the corresponding pupil Du Bois-Reymond calls this kind of hemierania sympatico-tonica. Moellendorf,[1] from his observations, thinks that hemierania is based on the appearance of a paralytic condition of the vasomotor nerves controlling the carotid artery of one side, which causes relaxation and distention of the arteries of the brain. Indeed, he was able to ascertain, by ophthalmoscopic examination, that during the paroxysms of hemierania the arteria and vena centrales retinæ and the choroidal vessels of the suffering eye were much dilated, but became again normal after the cessation of the paroxysm, while the vessels of the other eye remained normal all the time. Moellendorf, however, forgot to mention whether this condition was observed at the beginning or at the end of the paroxysm, and it is therefore possible that the paralytic condition of the vasomotor nerves appeared after their tetanic state. But should there really be a primary paralysis of the vasomotor nerves as cause of hemi-

[1] Über Hemicrania, Virchow's Archiv, xli., Heft. 3 und 4, p. 385.

crania, we should then distinguish two kinds of this neuralgia, the "hemierania sympathico-tonica" of Du Bois-Reymond, and the "hemierania sympathico-paralytica" or "neuro-paralytica" of Moellendorff.

The pain accompanying hemierania, Du Bois-Reymond explains by the tonic contraction of the muscular fibres of the vessels, deeming it analogous to the pain felt during tetanic contractions of voluntary muscles or of the unstriped muscles of the uterus, intestines, etc. In the paralytic form of hemierania, the pain would be caused by pressure of the dilated vessels upon the sensitive nerves, while pressure upon the vasomotor centre in the oblong medulla, upon the origin of the pneumogastric nerve, etc., would explain the vomiting and the other symptoms of hemierania.

With regard to the treatment of hemierania, the most rational and the most efficient, as would be expected, is the galvanization of the cervical sympathetic or of the cilio-spinal region. To corroborate this assertion I could bring quite a number of illustrations from my own practice, but suffice

it to say, that almost all my patients with sick-headache have been immediately relieved from the attack by the galvanization of the cervical sympathetic or of the regio cilio-spinalis. I have two cases on record where the attacks have not reappeared for about two years.

BASEDOW'S DISEASE.

This affection is characterized by palpitation of the heart, enlargement of the thyroid gland, and exophthalmos. When first described by Basedow, the disease was considered as dependent on general anæmia, but Koeben,[1] and after him all the modern pathologists, unanimously ascribes this disease to the affection of the sympathetic. Indeed, nearly all the symptoms can be produced experimentally on animals by section and irritation of the cervical sympathetic, as we know from the experimental researches of Budge, Claude Bernard, and others. This assumption was still further confirmed by Heinrich Müller's discovery of the orbital muscle and other muscular structures, which produce pro-

[1] De Exophthalmo ac struma cum cordis affectione. Disser. inaug., Berlin, 1855.

trusion of the eyeball when the cervical sympathetic is irritated (as demonstrated by him on an executed criminal).[1] Finally, several *post-mortem* examinations of persons affected with Basedow's disease elucidated a pathological condition of the cervical sympathetic (Trousseau, Virchow, Recklinghausen). It consists chiefly in the increase of the connective tissue and atrophy of the nervous elements of the cervical sympathetic, especially of the upper and lower ganglia.

With regard to treatment, I will mention the good results obtained by Dusch[2] from the galvanization of the cervical sympathetic. On using ten or twenty elements, he noticed a considerable decrease of the action of the heart, the number of its pulsations diminished during eight days from 130 to 70 and 64, and the exophthalmos became considerably reduced. Similar favorable results have been reported by Eulenburg and Guttmann.[3]

[1] H. Müller, Verhandl. der Würz. Med. Gesellsch., 1859, Bd. 10, p. 49.

[2] Lehrbuch des Herzkrankheiten, p. 362.

[3] Die Pathologie des Sympathicus. Griesinger's Archiv, Bd. I., Heft 2, p. 453.

PROGRESSIVE MUSCULAR ATROPHY.

This disease, although mentioned previously, by Charles Bell and Abercrombie, has become generally known by the classical researches of Duchenne, Aran, and Cruveilhier. Duchenne describe the disease as a primary muscular affection, with fatty degeneration of the muscles, while Cruveilhier considered the paralysis of the muscles a consequence of the primary atrophy of the anterior roots of the spinal nerves. Schneevogt and Jaccoud have discovered at the *post mortem* fatty degeneration of the sympathetic, and attribute therefore the progressive muscular atrophy to a primary affection of the sympathetic.

Remak has discovered in progressive muscular atrophy a remarkable phenomenon, called by him "diplegic contractions." These contractions are produced in the paralyzed muscles when the anode of a galvanic current is applied to the "irritable zone" situated between the first and fifth cervical vertebræ (especially in the fossa carotica), and the cathode below the fifth cervical vertebra. He also

considers progressive muscular atrophy as a disease of the sympathetic ganglia and of the cervical spinal cord.

With regard to treatment, I will only mention a recent authentic case of Nesemann,[1] where a patient, affected with this disease in the highest degree, was radically cured by the galvanization of the sympathetic. The correctness of the diagnosis was ascertained by the microscopic examination of excised pieces from the paralyzed muscles before the treatment.

For the sake of abbreviation, I will merely enumerate the following diseased conditions, also considered as dependent upon affection of the sympathetic: Angina pectoris;[2] hyperæsthesia of the mesenteric plexus (enteralgia, colic); hyperæsthesia of the solar plexus; hyperæsthesia of the hypogastric plexus (menstrual colic); hyperæsthesia of the spermatic plexus (irritable testis, irritable uterus), Addison's disease, etc.

[1] Berlin. Klin. Woch., 1868, No. 37. [2] Without cardiac disease.

IV.

THE ACTION OF THE GALVANIC CURRENT UPON THE PNEUMOGASTRIC NERVE.

The pneumogastric nerve (nervus vagus) is the only cerebral nerve the section of which on both sides is absolutely fatal. The pneumogastric and the accessory nerves must be considered as the two roots of one nerve, the pneumogastric containing the centripetal fibres and but few motor fibres, and the accessory exclusively centrifugal ones.

The pneumogastric contains:

1. Motor fibres for the muscles of the soft palate, of the pharynx, larynx (mostly in laryngeus inferior or recurrens), for the muscular fibres of the bronchial tubes, of the œsophagus, of the stomach, and perhaps also of the intestinal canal and uterus.

2. Secretory fibres for the glands of the gastric mucous membrane, and for the kidneys (Bernard).

3. Inhibitory fibres for the heart (Ed. Weber, Budge).

4. Sensitive fibres for the whole respiratory apparatus, for the digestive apparatus (from the velum palati to the pylorus), and for the heart.

5. Accelerating and inhibitory fibres for the centre of respiration (Rosenthal).

6. Accelerating and inhibitory nerve-fibres for the vasomotor centre; the first contained in the laryngeus superior (Aubert and Roever); the second contained, in some animals, in a separate branch of the vagus called nervus depressor (Ludwig and Cyon).

7. Inhibitory nerves for the secretion of the panereas, etc.

Irritation of the vagus above its junction with the accessory nerve produces contractions in the larynx, pharynx, and œsophagus. Section of its cervical portion causes paralysis of the laryngeal muscles, acceleration of the heart's pulsation, and retardation of the inspiratory movements. It also suppresses the sugar-formation in the liver.

Irritation of the peripheral end of the vagus,

divided in the neck, produces spasmodic contraction of the laryngeal muscles (spasm of the glottis); the same is produced by the irritation of the peripheral end of the laryngeus inferior. It further retards the heart's action to complete paralysis in diastole. It contracts the smooth, muscular fibres of the bronchi, thus diminishing their calibre, and contracts also the stomach, intestines, and uterus.

Irritation of the central cervical end of the pneumogastric accelerates the inspiratory movements to a tetanic inspiration, increases the production of sugar and the salivary secretion, but diminishes the pancreatic secretion. It diminishes the blood-pressure, and retards the heart's pulsation.

Section of the laryngeus inferior paralyzes the laryngeal muscles. The recurrent of one side is often paralyzed through pressure by aneurism of the aortic arch.

Irritation of the central end of the laryngeus superior retards the inspiratory movements to complete cessation of respiration (Rosenthal), and

increases the blood-pressure, through contraction of all the arteries.

Lastly, the irritation of the central end of the depressor dilates all the arteries, and therefore diminishes the blood-pressure (Cyon and Ludwig).[1]

By irritating either the trunk of the vagus, or the laryngeus superior, some experimenters (Krimer, Romberg) have produced coughing, while others could not arrive at the same result.

In regard to this phenomenon, which is so important in a clinical point of view, Nothnagel's[2] very exact experiments have established the following facts:

Irritation of the mucous membrane of the larynx, above the vocal cords, does not excite coughing.

It is, however, called forth instantly by the slightest irritation of the mucous membrane of the larynx below the voeal cords, of that of the

[1] L. Hermann, Grundriss der Physiologie des Menschen, Berlin, 1870, p. 317.

[2] Nothnagel, Zur Lehre vom Husten. Virchow's Archiv, Bd. 44, p. 25.

trachea, and of the bronchial tubes, especially at the place of bifurcation.

Irritation of the pleura in its healthy or inflamed condition, as well as irritation of the trunk of the vagus, and of the laryngeus superior, does not excite coughing.

The cough which so often occurs during pleuritis depends, therefore, not upon the irritation of the pleura, but upon the accompanying irritation of the bronchial mucous membrane; and, when this latter irritation is not present, pleuritis may exist without any cough, as was already observed by Laennec, Andral, Wintrich, and others.

Nothnagel explains the absence of cough when the nerve-trunk is irritated, and its invariable appearance at the slightest irritation of the respiratory mucous membrane, by the physiological law, according to which, reflex phenomena are provoked more readily at the terminations of a nerve than in its trunk.

The origin of the pneumogastric nerve is in the medulla oblongata, at the very vital point (*Nœud vital* of Flourens) which is the centre of

respiration, and the destruction of which instantly suppresses the respiration, and causes death.

The rhythmical function of this centre of respiration is constantly influenced by nerve-fibres contained in the pneumogastric. They are of two kinds, accelerating and inhibitory; the latter contained, according to Rosenthal, in the laryngeus superior, and, according to Pflüger and others, contained both in the laryngeus superior and inferior. The influence of the accelerating fibres is always prevalent in the normal condition, and also during irritation of the upper end of the vagus. With its intense irritation the respiration becomes tetanic, the diaphragm remaining permanently contracted (prolonged inspiration—Traube).

The normal stimulus for the respiratory centre is a certain amount of oxygen and carbonic acid in the blood. The intensity of respiration augments with the increase of carbonic acid. This condition, called dyspnœa, occurs when there is an obstacle to the oxygenation and decarbonization of the blood, for instance, in affections of the lungs, etc. On the other hand, the respiratory

movements cease altogether (apnœa) when the blood is overcharged with oxygen and contains but little carbonic acid, as after powerful artificial respiration.

These conditions of dyspnœa and apnœa can be produced by saturating locally the blood contained in the medulla oblongata with carbonic acid and with oxygen. The first happens, for instance, when the blood stagnates in the vessels of the medulla oblongata, after ligation of the cervical arteries (Kussmaul and Tenner). If the overcharge of the blood with carbonic acid still continues to increase, it then not only irritates the respiratory centre, producing dyspnœa, but it also irritates the convulsive centre situated in the pons varolii, and produces general convulsions. A very prolonged privation of oxygen abolishes the irritability of the medulla oblongata, so that no stimulus, not even blood overcharged with carbonic acid, can longer call forth the respiratory movements (asphyxia).

Uspenski[1] has demonstrated that apnœa pro-

[1] Reichert's and Dubois's Archiv, 1869, p. 401.

duced by artificial respiration lowers the reflex irritability. Animals poisoned with strychnia and similar poisons are not affected with tetanus and convulsions, as long as a condition of apnœa is kept up by artificial respiration, which, if continued until the poison is eliminated from the system, will save the animals, and prevent the convulsions altogether.

During apnœa produced by artificial respiration, reflex irritation of the vagus does not retard the heart's pulsations.

INHIBITORY NERVES.

One of the most remarkable properties of the pneumogastric nerve is its inhibitory influence upon the heart. Ed. Weber made the important discovery that irritation of the pneumogastric (mechanical, chemical, electrical) diminishes the frequency of the heart's contractions, and intense irritation produces paralysis of the heart in diastole. A certain degree of excitation at the origin of the vagus in the medulla oblongata must necessarily exist during the whole life, because sec-

tion of the pneumogastric invariably produces a sudden increase of the heart's pulsations.

The irritation of the vagus can be produced through reflex action, for example, by irritating the abdominal viscera (Goltz), or different sensitive nerves (Ludwig and Loven).

Like the vagus, some other nerves have been found possessing a similar property, and are called inhibitory nerves. When irritated, they moderate or abolish the action of the corresponding organ. We have already mentioned the splanchnic nerve, which is an inhibitory nerve for the peristaltic movement of the intestines (perhaps in consequence of its action upon the abdominal vessels). In the same way is the laryngeus superior an inhibitory nerve for the respiratory centre, and the depressor for the vasomotor centre.

Besides inhibitory nerves, we must admit the existence of inhibitory centres. Such inhibitory centres for the reflex action of the spinal cord have been discovered in the brain by Setschenow.[1]

[1] Setschenow, Hemmungsmechanismen für die Reflexthätigkeit des Ruckenmarks. Berlin, 1863.

They are situated in the thalami optici and corpora quadrigemina, and, when irritated, diminish or abolish the reflex function of the spinal cord. During life, these centres are always kept in a certain degree of excitation by the action of the circulating blood (which is a stimulus for the central organs—Setschenow), and this explains the increase of the reflex activity after decapitation. Moreover, these centres can be excited by the irritation of centripetal nerves. Setschenow explains also the action of certain poisons (morphine) in diminishing or suspending the reflex movements, by supposing them irritatants to the cerebral centres inhibitory of the reflex activity of the spinal cord.

With regard to the action of the galvanic current upon the pneumogastric nerve, I first sought to ascertain whether the nerve could be reached by the external application of the electrodes to the skin. For this purpose, I made upon a rabbit a similar experiment to that I described in speaking of the sympathetic. Through an incision made in the skin, I introduced the nerve of a galvanoscopic frog, brought it in contact with the pneumogastric

nerve, the rest of the frog-preparation being carefully isolated. When passing a current from twenty Siemens elements through the skin, in the direction of the vagus, the galvanoscopic frog exhibited vivid contractions at the closing, the opening, the reversal, and at large fluctuations, of the current.

Donders[1] found that the vagus in living animals, when traversed by the galvanic current, obeys the contraction-law of Pflüger. He observed also that its irritability is always lowered in the anelectrotonic region, but is very seldom increased in the catelectrotonic region.

To ascertain the influence of the current in exciting cough, when traversing the vagus or its branches, I have experimented upon cats and dogs, animals in which coughing is distinct. For the want of assistance, these experiments could not be instituted with the necessary exactness, and were not sufficiently numerous to lead to positive results. I shall, however, resume them under more favorable circumstances, and publish the results in

[1] Virchow's Jahresb., 1869, Bd. I., Abt. I., p. 114.

another place. Although the animals did not actually cough when the vagus was traversed by a galvanic current, yet they made efforts, as if preparatory to coughing. This was especially the case under the influence of the ascending current, under which, also, the retardation of the heart's pulsations was more marked.

On the living man the effect of galvanization of the vagus is very frequently observed, especially with reference to the excitation of cough. The application of the electrodes of a moderate current to certain regions of the neck, especially in some persons, will invariably call forth a peculiar irritation in the throat, followed by coughing, which appears at the cathodic closing, and sometimes also at the anodic opening, and increases with the intensity and fluctuations of the current.

In galvanizing the pneumogastric in the usual way in the living subject, the current does not reach the nerve in sufficient density to produce the chief phenomenon of marked irritation of the vagus, a considerable diminution in the heart's pulsations. Under favorable circumstances, however, it

may suffice to modify the action of the heart as well seen in the change of the radial pulse, represented by the sphygmograph.

ASTHMA.

My attention was first called to the subject of asthma by the excellent work of Salter,[1] who considers this disease as a peculiar kind of dyspnœa, called forth by a spasm of the bronchial tubes, which is caused by a reflex affection of the pneumogastric. The author, himself a sufferer from this distressing disease, has given a most admirable and graphic description of the paroxysms of asthma, and many valuable contributions concerning the etiology, pathology, and treatment, of this disease. Referring the reader for particulars to Salter's work, I shall make a few remarks regarding the nature of the disease, and the mode of treatment I have adopted. The spasm theory of asthma, supported by Cullen, was generally accepted by the profession; but it became gradually abandoned by subsequent observers. Corvisart found

[1] Henry Hyde Salter, F. R. S., on Asthma, London, 1860.

that asthmatic paroxysms may be caused by diseases of the heart and large vessels; Laennec and Louis have shown that emphysema of the lungs is one of the most frequent causes of the fits of dyspnœa which are commonly called asthma; and Budd rejects altogether the nervous nature of asthma, at least with reference to the bronchial tubes, but admits in a few exceptional cases the possibility of spasm, or paralysis of the diaphragm and other muscles of inspiration. Walshe[1] and others suppose that a paralytic condition of the muscular fibres of the bronchial tubes may also be the cause of asthma. Todd[2] has proposed a very ingenious theory of asthma, for which an objective cause in the lungs is not absolutely necessary. He thinks it dependent merely upon a particular *materies morbi* in the blood, which poisons the respiratory nerves or their centre, and perverts their functions, thus producing a subjective sense of breathlessness, which may or may not be accompanied with bronchial spasm. Salter revived the spasm theory of

[1] Walshe, Diseases of the Lungs and Heart, p. 337.

[2] Medical Times and Gazette, December, 1850.

asthma, supporting it by appropriate arguments, and entirely rejected the paralysis theory. He admits emphysema as a sequela, but not as a cause, of asthma, which may be complicated with diseases of the heart and lungs, or may exist as an independent idiopathic affection. Asthma is a spasmodic contraction of the bronchial tubes caused by reflex irritation of the pneumogastric, and induced by excitation of the respiratory or gastric mucous membrane, of the cutaneous surface, etc. In some cases the source of irritation is central—in the brain; in others, again, the exciting cause of the asthmatic paroxysm appears to be humoral, the contaminate blood being the irritant, which calls forth the bronchial spasm through the intervention of the pneumogastric.

Asthma, then, according to Salter, is essentially and exclusively a nervous disease, the nervous system being the principal seat of this pathological condition. Indeed, the periodicity of the paroxysms, during the intervals of which the patient may be perfectly healthy, gives the best evidence of the correctness of his views. Moreover, the

remedies against the asthmatic attacks are antispasmodics, nervous depressants, such as tobacco, stramonium, chloroform, chloral (Biermer). By the influence of these remedies, as well as by mental emotion, the most agonizing attack may be completely checked—a circumstance illustrative of the purely nervous nature of the affection. A very frequent symptom of asthma is profuse diuresis at the beginning of the paroxysm. This abundant secretion of pale, limpid urine is of the same nature as that in hysteria and other nervous diseases. Furthermore, the *post-mortem* examination of asthmatics (in cases of uncomplicated asthma), who have died from some other cause, shows a perfect anatomical integrity of both the organs of respiration and of circulation. There are cases of asthma, recorded by Gairdner [1] and others, where at the *post mortem* a neuromatous tumor of the vagus was found, or an exostosis pressing upon one of the pneumogastric nerves.

According to Salter, the phenomena of asthma are invariably the result of a spasmodic contraction

[1] Edinburgh Medical and Surgical Journal, 1850. Salter, *op. cit.*, p. 93.

of the bronchial tubes; and whoever has observed a paroxysm of asthma will probably have been impressed with the same idea. The existence in the bronchi of a circular layer of smooth muscular fibres[1] renders such a spasm possible. Moreover, Williams, Longet, and Bert,[2] have produced contraction of the bronchial tubes by electrical irritation of the lungs or of the vagus.

Wintrich[3] thinks that asthma depends on a tetanic contraction of the diaphragm, which he invariably found very deep, and the lungs expanded, during the asthmatic paroxysm. The same was observed by Bamberger.[4] But the assumption of a prolonged tetanic contraction of the diaphragm cannot be admitted, since Duchenne[5] has demonstrated that it necessarily leads to asphyxia within a few minutes.

[1] Kolliker, Gewebelehre, 1867, p. 473.

[2] P. Bert, Leçons sur la Physiologie comparée de la Respiration, Paris, 1870.

[3] Wintrich in Virchow's Handb. der spec. Pathologie and Therapie, Bd. V., Erlangen, 1854.

[4] Bamberger, Ueber Asthma Nervosum, Würzb. med. Zeitsch., 1865.

[5] Duchenne, Electrisation localisée, Paris, 1855, p. 488.

The most recent writer on asthma, Biermer,[1] considers the asthmatic attack dependent on a tonic contraction of the small and middle-sized bronchial tubes, which impedes the expiration of the air contained in the lungs; hence their expanded condition and the deep situation of the diaphragm.

Although admitting the *bronchial spasm* as a very frequent cause, I still think that a *paralytic condition* is also capable of producing the phenomena of asthma. We have seen that dyspnœa takes place whenever there is an excess of carbonic acid in the blood generally, or only in the vessels of the respiratory centre. This condition can be produced, not only by spasm of the bronchial tubes, but also by paralysis; in both cases, from the sudden suspension of the respiratory movements, there must be a rapid accumulation of carbonic acid in the vessels of the respiratory centre, accompanied by a high degree of dyspnœa. Again, under the influence of the vasomotor nerves, a sudden change

[1] A. Biermer, Ueber Bronchialasthma, Sammlung Klinischer Vorträge, Leipzig, 1870.

may primarily take place in the calibre of the vessels of the respiratory centre, which will also call forth a sudden appearance of dyspnœa. In my opinion, therefore, neither spasm nor paralysis of the bronchial tubes is essential to the production of an asthmatic attack; it can be produced by any circumstance capable of causing a sudden appearance of dyspnœa. But, whatever be the origin of the asthmatic attack, it is necessarily caused by the intervention of the pneumogastric. This nerve may be excited at its terminations in the lungs, the irritant being some substances inhaled with the air, or at its terminations in the stomach (peptic asthma), or the irritant may exist at any distant point, and affect the pneumogastric through reflex action.

Practically, we must distinguish two varieties of asthma. One, the uncomplicated, idiopathic, purely nervous asthma. The other, the symptomatic asthma, which accompanies organic diseases of the lungs and heart. The mechanism of the asthmatic paroxysm is, however, essentially alike in both. It takes place when the accumula-

tion of carbonic acid in the vessels of the respiratory centre has reached a degree which necessarily excites the sudden dyspnœa. Since in organic asthma the cause of the dyspnœa exists permanently, the patient is never completely free of it, and there are no regular intervals of absolutely healthy breathing.

But even the idiopathic, nervous asthma does not remain so indefinitely. If of long standing, it has a tendency to produce some organic affections, of which the most frequent is hypertrophy of the bronchial muscle with permanent thickening of the bronchial walls and narrowing of the air-passages. Further sequelæ of asthma are emphysema of the lungs, and hypertrophy and dilatation of the right side of the heart.

Finally, those affected with this disease acquire a peculiar characteristic asthmatic physique. The asthmatic becomes "round-backed, high-shouldered, and stooping, but, while the body is bent forward, the head is thrown back, and buried, as it were, between the elevated shoulders" (Salter), and the chest assumes a peculiar configuration.

Asthmatics of long standing are almost invariably thin, emaciated, their complexion becomes cyanotic, the eyes turgid, watery, and prominent, and the voice feeble and hoarse.

TREATMENT OF ASTHMA BY GALVANIZATION OF THE PNEUMOGASTRIC.

The final conclusion at which Salter arrived is, that asthma is incurable, although much can be done to alleviate the severity and frequency of the paroxysms. He cautions his readers against the employment of "galvanism—the passing of galvanic shocks through the chest. I object to it, both on theoretical and practical grounds. What idea could have originally suggested it, I am at a loss to imagine, unless it were the paralysis theory of the disease—that asthma depended on loss of power of the bronchial muscle, or the muscles of the thoracic parietes, etc."[1] Judging from Salter's own statement, especially from the expression, "passing galvanic shocks through the chest," he

[1] Salter, *op. cit.*, p. 185

must have probably meant the induced currents, which certainly do much harm in asthma, aggravating the existing attack, and bringing one on if the patient be free from it. The same would be true in regard to the galvanic current, if improperly used, especially if shocks and large fluctuations of the current-density are not avoided by means of the rheostat. Had Salter, on the publication of his valuable work, been acquainted with the modern physiology of the nerves, especially had he known of their wonderfully-lowered irritability in the anelectrotonic state, he would certainly have recommended the constant galvanic current as the most rational and efficient remedy in asthma. Indeed, the success I have obtained in the treatment of this affection by the galvanization of the pneumogastric nerve has far surpassed my own expectations. Whether the idiopathic asthma can be radically cured by the galvanic current I am yet unable positively to assert, but I have no doubt that the asthmatic paroxysms can be kept off for an indefinite time, and that every single attack may often be checked. This is certainly of

the utmost value to the sufferer, whose agonies, from the sense of impending suffocation and struggle for breath, are extreme during the paroxysm, of which Salter says: "To be fairly imagined, it should be witnessed; to be fully appreciated, it should be experienced."

After having for several years used the galvanic current in the treatment of asthma, I learned that Brenner,[1] too, had recourse quite recently to the galvanization of the vagus, with an excellent result, in an obscure affection which he could not more nearly define, but which, according to his description, must have been asthma.

When I first commenced to treat asthma, I assumed that the irritability of the pneumogastric is exalted in this disease; I therefore tried to produce a condition of anelectrotonus in the pneumogastric nerve, and my first experiment was a complete success. The patient, who, during a most violent attack, could not enter my house without being supported, left greatly relieved and breathing quite normally. I repeated the treat-

[1] Brenner, *op. cit.*, Bd. II., p. 84.

ment on the same patient until it was no longer required, the paroxysms having entirely disappeared. I found, after a while, however, that the asthmatic paroxysm cannot be controlled in all cases by producing the anelectrotonic state in the vagus. In some patients it would be instantly checked as soon as the anode was applied to the vagus, and the circuit closed; in others it would be only more or less favorably modified, and in others, again, it would not be influenced at all by the current; it was sometimes even aggravated. Then the idea suggested itself to my mind that, possibly, the asthmatic attack may not always be caused by a spasmodic contraction of the air-passages (as assumed by Salter), but that in some cases it may be brought on by a paralytic condition of the bronchial tubes. Accordingly, in cases like those last above named, I tried to call forth a catelectrotonic state in the pneumogastric, and saw a decidedly beneficial effect. It is, however, possible that in these cases the favorable result must not be ascribed to the influence of the catelectrotonus upon the paralyzed bronchial tubes, but to the abnormal

reaction of the pneumogastric nerve to the galvanic current. This would be analogous to the abnormal reaction of the auditory nerve, as already stated, and also to that of the motor and sensitive nerves, as will be seen in another chapter. It is remarkable that, in the great majority of cases of asthma, the catelectrotonic state abolishes the asthmatic attack.

The general rules I follow in the treatment of asthma are as follows: By means of the polar method I endeavor to call forth a catelectrotonic or anelectrotonic condition of the vagus, according to the character of the asthma. The current-density is controlled by an accessory circuit in which the rheostat is intercalated, and every large fluctuation carefully avoided. I commence with a very weak current, gradually increasing its intensity until the severity of the attack has abated, when I begin slowly and gradually to diminish the number of resistances in the accessory circuit, and imperceptibly break the current. The duration of the *séance* is from two to ten minutes, the treatment being repeated at first daily, and afterward three times and twice a week. The patient must

be cautioned not to drop the treatment abruptly, but to continue it at some intervals.

The following cases are given as illustrations:

CASE XIII.—*Asthma. Galvanization of the pneumogastric. Recovery.*

Mr. P., forty-three years old, commenced to be asthmatic in his ninth year, after whooping-cough. The symptoms, at first slight, increased every year in severity and frequency, until they assumed the true character of asthma, appearing in paroxysms, between which the patient had no difficulty of breathing. There were especially some circumstances which would always call forth an attack; for instance, some articles of diet, and especially a late dinner. Sexual intercourse would invariably be followed by an attack, and so also would the least cold. There were some places or houses where he could never remain over-night without suffering from asthma, while in others, on the contrary, he felt quite free from it. In this case the galvanization of the pneumogastric (anelectrotonus) was followed immediately by a beneficial effect. Since

the first treatment, which was occasionally repeated, the patient has not had a single attack during the remainder of the winter, although he was out every day even in the most inclement weather.

Another patient, the aunt of the above-mentioned, fifty-five years old, had been affected with asthma since her childhood, and presented the most characteristic appearance of the asthmatic physique. In her case, it was not the anelectrotonic but the catelectrotonic condition of the vagus that afforded great relief.

Case XIV.—*Asthma. Galvanization of Pneumogastric. Recovery.*

Mrs. C., aged thirty, sent to me by Dr. Marion Sims, December 9, 1868. She has been affected with severe asthma from her childhood, and different kinds of treatment have been used without any benefit. Galvanization of the vagus (catelectrotonus) has immediately relieved her from an attack, and she remains still free from asthma, after having been treated fifteen times.

CASE XV.—*A severe attack of asthma checked by galvanization of the vagus.*

Mr. J., aged thirty-five, suffered from severe asthma, for which he had been treated by many excellent physicians. Dr. Elsberg sent him to me September 21, 1869, during an intense attack, which had already lasted for a fortnight, entirely depriving him of sleep. After the first application of the galvanic current, by means of which I endeavored to produce a condition of ancelectrotonus of the vagus, he slept very comfortably the whole night, and the paroxysm disappeared.

CASE XVI.—*Hay-asthma. Galvanization of the vagus. Disappearance of all morbid symptoms.*

Mr. N., twenty-two years old, is attacked by hay-asthma every year during six weeks, commencing with the last week in August. The whole day he is then troubled with paroxysms of sneezing and lachrymation, accompanied with inflammation of the conjunctiva, fauces, soft palate, and bronchial tubes, and with a considerable degree of fever. The greater part of the night he struggles for

breath, so that the next day finds him exhausted and suffering from headache. His pulmonary symptoms became at last so alarming, that an eminent physician of this city gave a very unfavorable prognosis, suspecting pulmonary consumption. Galvanization of the vagus (catelectrotonus), August 30, 1868, produced a marked beneficial effect upon the condition of the patient. The treatment was continued daily during a week, when all the morbid symptoms, which would have lasted yet for several weeks, entirely disappeared. Since that time the general health of the patient has very much improved.

Besides asthma, I have tried the galvanization of the pneumogastric in whooping-cough and other obstinate diseased conditions, where I presumed this nerve to be affected. My observations, however, are not sufficiently numerous as yet to admit of any positive result.

I cannot conclude this chapter without calling the attention of the profession to an interesting and obscure affection characterized by attacks of de-

pression, with a marked diminution of pulse, and which can be traced to the inhibitory influence of the vagus upon the action of the heart. It has already been mentioned that the inhibitory fibres of the vagus for the heart can be irritated, either directly or by way of reflex action. Goltz has demonstrated that, by irritating the abdominal nerves, for example in the frog by striking upon its abdomen, the heart comes to a complete stand-still in diastole, in consequence of the reflex irritation of the vagus. He has shown, moreover, that this paralysis of the heart can be prevented when, simultaneously with the irritation of the abdominal nerves, a strong irritation of the cutaneous nerves is effected, because an intense irritation of centripetal nerves diminishes or abolishes the reflex activity.[1]

The correctness of Goltz's statements cannot only be easily ascertained by experimenting on animals, but is daily witnessed in the human subject. It is a well-known fact that a blow upon the abdomen, especially in its expanded condition after a full meal, is very dangerous, and there have been

[1] Goltz, Zur Lehre von der Hemmung der Reflexerscheinungen, p. 46.

instances of sudden death after such a blow, in consequence, no doubt, of paralysis of the heart through reflex action on the pneumogastric. I have had many times the opportunity of convincing myself and others, during the operation of ovariotomy, that the pulse becomes small and irregular as soon as the peritonæum is opened and subjected to the irritating influence of the air. The so-called abdominal pulse in peritonitis must be explained in the same way, by reflex action of the abdominal nerves upon the inhibitory fibres of the pneumogastric. I ascribe the fatal termination of operations on the peritonæum in many instances to the same cause. It often happens after such operations that a collapse sets in, accompanied by a small, irregular pulse and vomiting, and at the *post mortem* no peritonitis is found. In such cases death is undoubtedly caused by paralysis of the heart, induced by reflex irritation of the pneumogastric nerve. I have, therefore, proposed to use, during surgical operations upon the peritonæum, an intense irritation of the skin by an induced current, to prevent paralysis of the heart.

The following case is illustrative of the part which the inhibitory function of the vagus plays in some obscure affections:

Mr. K., aged fifty-four, merchant, of a good constitution, and formerly of excellent health, and very active, for the last few years suffered much from dyspepsia, and at times would become very low-spirited and depressed, without any particular cause. He has consulted several eminent physicians, and, as no organic disease could ever be detected, the majority considered him a hypochondriac. When I examined him, in December, 1868, I found his liver somewhat enlarged, and a great deal of tenderness in the right hypochondriac region and also corresponding to the seat of the pancreas. The urine contained a considerable amount of oxalate of lime. After having observed the patient for some time, I was called in during one of his fits of depression, and found him lying on a sofa, in a very apathetic condition, pale, and talking very little, in a low voice. I was much surprised to find his pulse 45, his normal pulse being always about 75. The sounds of the heart and its pul-

sations were very feeble and hardly perceptible. Similar attacks of depression, as he called them, occurred once a week or once a fortnight. It was evident to me that the patient exhibited the phenomena of reflex irritation of the vagus, induced by sensitive abdominal nerves of some diseased viscus.

I prescribed the use of Vichy and other internal remedies, simultaneously with which I galvanized the pneumogastric nerve, three times a week, with a descending current. The patient has very much improved, and has not had these attacks any more.

I think the reflex irritation of the vagus may explain some cases of hypochondriasis. We find that ancient physicians were acquainted with the fact that abdominal obstructions, and diseases of the abdominal viscera in general, act upon the mind in a depressing manner, and have a tendency to produce hypochondriasis.

I have now under observation a very interesting case, in which the direct irritation of the pneumogastric can be produced by the galvanic current, viz., a marked retardation of the heart's action.

The patient, about fifty-two years old, was operated upon last year for epithelioma of the lip, which was soon followed by a new tumor on the right side of the neck, near the angle of the lower jaw. The second tumor was also removed by a very skilful surgeon of this city, and was likewise followed by the development of a new tumor in its vicinity, in consequence of which the patient applied to me for electrolytic treatment. He is very nervous, and scarcely able to bear any pain; but, as he manifests unmistakable signs of atheromatous condition of the arteries, I am unwilling to put him under the influence of an anæsthetic. I am therefore obliged to employ comparatively weak currents; but even these, if exceeding a certain intensity and duration, will affect the pneumogastric and call forth phenomena of its irritation. The patient is suddenly attacked by a paroxysm of extreme depression, breathlessness, and pain in the præcordial region; he becomes pale, and the pulse falls to fifty, while it is usually over seventy. The paroxysm terminates as suddenly as it appeared.

THE END.

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